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MODEL
291B

Instruction Manual

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BRIDGES
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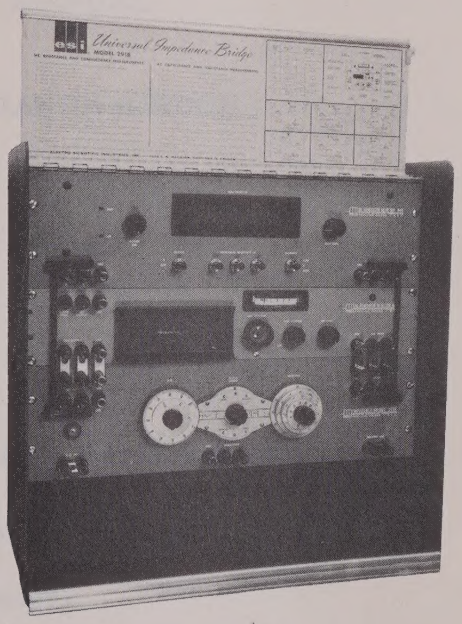
ACCESSORIES

OCTOBER 1962

MODEL
291B

Instruction Manual

IMPEDANCE BRIDGE



including

Model 290A
IMPEDANCE BRIDGE

Model 840
DC GENERATOR DETECTOR

Model 860
AC GENERATOR DETECTOR

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INSTRUCTION MANUAL

for

MODEL 291B IMPEDANCE BRIDGE

CONSISTING OF:

Introduction

Specifications

Model 290A Impedance Bridge Instruction Manual

Model 840 Instruction Manual

Model 860A Instruction Manual

Lid Instructions from 291B Bridge

DESCRIPTION

The MODEL 291B UNIVERSAL IMPEDANCE MEASURING SYSTEM provides for precision measurements of resistance, conductance, inductance, and capacitance. For capacitors and inductors, it also measures the dissipation factor (D) and storage factor (Q).

Modern circuit design, close manufacturing tolerance and highest quality material permit a conservative accuracy rating of ±0.05% for resistance and conductance, ±0.1% for inductance and capacitance. Comparative measurements can be made to five significant figures using the 120,005 divisions of dial resolution provided by the unique ESI Dekadial®.

The 291B system is designed for maximum versatility. Terminals are provided so that ranges may be extended and special circuit connections can be made. Four-terminal resistance connections can be used to increase the accuracy of low resistance measurements. Three-terminal connections can be used to remove the effects of stray shunt circuits when measuring high resistance or inductance or low capacitance. DC bias can be applied when making inductance and capacitance measurements.

The system features the MODEL 290A IMPEDANCE BRIDGE, the MODEL 840 DC GENERATOR-DETECTOR, and the MODEL 860A AC GENERATOR-DETECTOR. These generator-detector units are especially designed as companions to the 290A bridge and provide generator and detector performance compatible with the high resolution and accuracy of the bridge.

The functional aluminum case protects the instrument during transportation and storage, and provides a convenient shielded work area for components under test. The units have standard size panels and may be individually rack mounted if desired.

The capacitance and inductance calibration can be adjusted by a variable capacitor in parallel with the standard capacitor. This allows for correction of long-term drift, so that accuracy equivalent to available standards can be achieved.

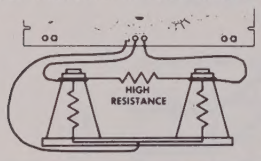
Resistance and conductance measurements are usually made with direct current because of the increased accuracy and the lack of stray reactance effects. Resistance and conductance measurements can be made using ac, but they may require external reactance compensation. Inductance and

capacitance measurements are made in terms of a two-element circuit with the same impedance as the unknown. The bridge dials read the values of this equivalent circuit. An equivalent parallel circuit is used for high Q inductors and high D capacitors. An equivalent series circuit is used for low D capacitors and low Q inductors.

An important feature of the 290A bridge is its ability to measure small three-terminal capacitors without zero-capacitance correction, and without the use of a separate guard circuit or Wagner ground. The bridge internal shielding eliminates internal stray capacitance in parallel with the unknown. Stray capacitance external to the bridge can be eliminated by using a shielded lead to the point of measurement.

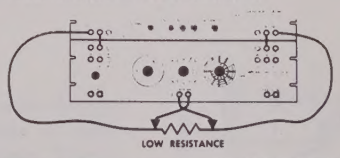
APPLICATIONS

THREE TERMINAL MEASUREMENTS



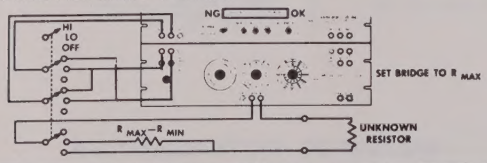
LESSENS LEAKAGE PROBLEMS

FOUR TERMINAL MEASUREMENTS

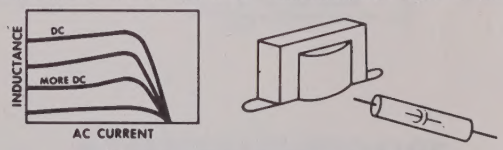


LESSENS LEAD AND CONTACT RESISTANCE PROBLEMS

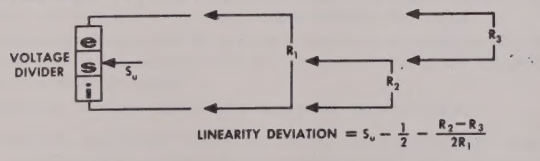
RESISTANCE LIMITS CHECKING



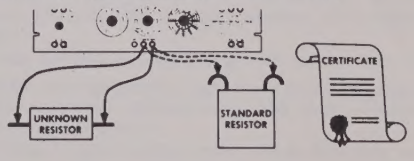
INDUCTANCE AND CAPACITANCE MEASUREMENTS WITH DC BIAS



VOLTAGE DIVIDER CHECKING



SUBSTITUTION MEASUREMENTS FROM 10 PPM

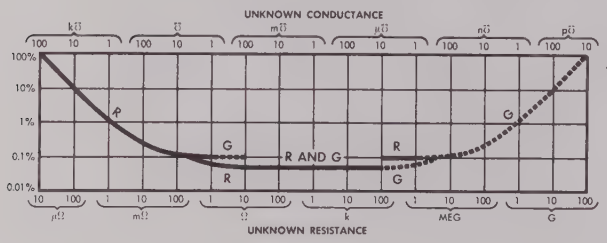


SPECIFICATIONS

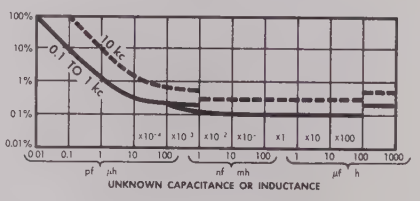
SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT	RANGES		ACCURACY △		
		MAGNITUDE	D or Q	L, R, C, G RANGE	MAGNITUDE	D or Q
R	R	0-1200 KILOHMS IN 7 RANGES;* 0.01 MILLIOHM PER DIAL DIV ON LOWEST R RANGE		HIGHEST	0.1% + 1 DIAL DIV	
				OTHER 5	0.05% + 1 DIAL DIV	
				LOWEST	0.1% + 1 DIAL DIV	
G	G	0-1200 MILLIMHOS IN 7 RANGES; 10 pmhos (1/100,000 MEGOHM) PER DIAL DIVISION ON LOWEST G RANGE		HIGHEST	0.1% + 1 DIAL DIV	
				OTHER 5	0.05% + 1 DIAL DIV	
				LOWEST	0.1% + 1 DIAL DIV	
L Series	L_s Q	0-1200 HENRYS IN 7 RANGES; 0.01 μh PER DIAL DIV ON LOWEST L RANGE	Q=0 TO 10.5 f_{kc} IN 3 RANGES 0.001 f_{kc} PER DIAL DIV ON LOWEST Q RANGE	HIGHEST	0.2% + 1 DIAL DIV + 1.2% x f_{kc}/Q	0.012 f_{kc} $(1+Q^2)$ + 0.02Q
				OTHER 5	0.1% + 1 DIAL DIV + 0.7% x f_{kc}/Q	0.007 f_{kc} $(1+Q^2)$ + 0.02Q
				LOWEST	0.2% + 1 DIAL DIV + 0.7% x f_{kc}/Q	0.007 f_{kc} $(1+Q^2)$ + 0.02Q
L Parallel	L_p D	0-1200 HENRYS IN 7 RANGES; 0.01 μh PER DIAL DIV ON LOWEST L RANGE	D=0 TO 10.5 f_{kc} IN 3 RANGES 0.001 f_{kc} PER DIAL DIV ON LOWEST D RANGE	HIGHEST	0.2% + 1 DIAL DIV + 1.2% x D f_{kc}	0.012 f_{kc} $(1+D^2)$ + 0.02D
				OTHER 5	0.1% + 1 DIAL DIV + 0.7% x D f_{kc}	0.007 f_{kc} $(1+D^2)$ + 0.02D
				LOWEST	0.2% + 1 DIAL DIV + 0.7% x D f_{kc}	0.007 f_{kc} $(1+D^2)$ + 0.02D
C Series	C_s D	0-1200 MICROFARADS IN 7 RANGES; 0.01 pf PER DIAL DIV ON LOWEST C RANGE	D=0 TO 10.5 f_{kc} IN 3 RANGES 0.001 f_{kc} PER DIAL DIV ON LOWEST D RANGE	HIGHEST	0.2% + 1 DIAL DIV + 0.5% x D f_{kc}	0.005 f_{kc} $(1+D^2)$ + 0.02D
				OTHER 5	0.1% + 1 DIAL DIV + 0.5% x D f_{kc}	0.005 f_{kc} $(1+D^2)$ + 0.02D
				LOWEST	0.2% + 1 DIAL DIV + 1.0% x D f_{kc}	0.010 f_{kc} $(1+D^2)$ + 0.02D
C Parallel	C_p Q	0-1200 MICROFARADS IN 7 RANGES; 0.01 pf PER DIAL DIV ON LOWEST C RANGE	Q=0 TO 10.5 f_{kc} IN 3 RANGES 0.001 f_{kc} PER DIAL DIV ON LOWEST Q RANGE	HIGHEST	0.2% + 1 DIAL DIV + 0.5% x f_{kc}/Q	0.005 f_{kc} $(1+Q^2)$ + 0.02Q
				OTHER 5	0.1% + 1 DIAL DIV + 0.5% x f_{kc}/Q	0.005 f_{kc} $(1+Q^2)$ + 0.02Q
				LOWEST	0.2% + 1 DIAL DIV + 1.0% x f_{kc}/Q	0.010 f_{kc} $(1+Q^2)$ + 0.02Q

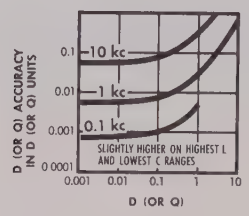
*Equivalent resistance measurements to 100,000 megohms are possible using the conductance ranges.

△ Accuracy specifications for inductors and capacitors apply for units with reasonably high Q (low D), at frequencies near 1 kc. The nominal frequency range is 100 cycles to 10 kc, with slight accuracy derating near the limits.

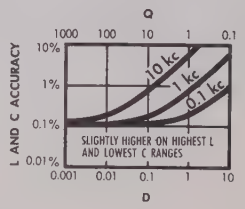


These curves show the specified accuracy for measurements of resistors and low loss inductors and capacitors.





The accuracy of inductance and capacitance measurements is influenced by the D or Q value. Graphs show the accuracy to be expected at various values of D or Q.



A C GENERATOR-DETECTOR
MODEL 860A

GENERATOR. Voltage: Adjustable from 0 to approximately 15 volts, with internal resistance of approximately 600 ohms.

Frequency: Determined by a plug-in network: accurate to 1%. A 1 kilocycle unit is supplied with the bridge; 0.1, 0.4 or 10 kilocycle are available from stock.

Isolation: Leakage capacitance to ground less than 30 pf.

DETECTOR. Indicator: Meter and electron-ray null indicator used for instantaneous response to signal changes. Dual display presents changes in both strong and weak signals.

Sensitivity: Approximately 20 microvolts; sharply tuned to the generator frequency to minimize response to harmonics and hum pickup.

Output: Terminals provided for meter or oscilloscope display.

POWER SUPPLY. 115 volt, 50/60 cycles.

D C GENERATOR-DETECTOR
MODEL 840

GENERATOR. Voltage: 10 volts with internal resistance of 60 ohms and 300 volts with internal resistance of 22 kilohms. Polarity reversible.

Isolation: Leakage resistance to ground greater than 10 terohms.

DETECTOR. Galvanometer: Light beam type with vibration damping. Coil resistance approximately 300 ohms; critical damping approximately 2000 ohms.

Sensitivity: A three-position switch selects 0.03, 0.60 or 12 microamperes per millimeter division.

Damping: A three-position switch selects the damping when using maximum galvanometer sensitivity.

PROTECTION. Circuit is designed so dc power output, at either 10 volts or 300 volts, cannot exceed 1 watt, which cannot damage either the bridge or the galvanometer.

POWER SUPPLY. 115 volts 50/60 cycles.

PHYSICAL SPECIFICATIONS

Model 291B with customed enclosure, as illustrated.
DIMENSIONS (in inches) ..... 19½ W x 19½ H x 12D
NET WEIGHT ..... 53 pounds

	Model 290A	Model 840	Model 860A
DIMENSIONS	19W x 5¼H x 8D	19W x 5¼H x 8D	19W x 3½H x 8D
NET WEIGHT	18½ Pounds	12 Pounds	10 Pounds

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BRIDGES AND ACCESSORIES

AUGUST 1962
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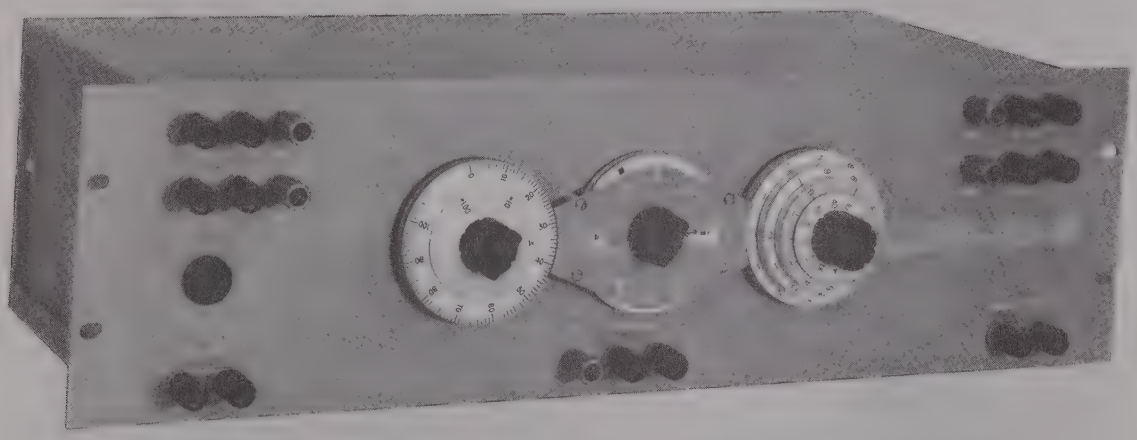

Model 290A
IMPEDANCE BRIDGE

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INSTRUCTION MANUAL

for

MODEL 290A UNIVERSAL IMPEDANCE BRIDGE

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1. ACCESSORIES REQUIRED

1.1 For DC Measurements:

The ESI Model 840 dc Generator and Detector is recommended for use with the Model 290A bridge. If other dc generator and detector units are used, they should meet the following specifications:

1.1.1. DC Generator

Isolation: Resistance to ground must exceed 10 terohms.

Do not exceed 400 volts open circuit.

Limit power output to 1 watt or less

For example:

1.5 volts in series with 0.5 ohms or more
10 volts in series with 25 ohms or more
300 volts in series with 25K ohms or more

1.1.2 DC Detector

Desired characteristics:

Sensitivity: Approximately 0.03 microamperes per millimeter. Critically damped by a few kilohms.

1.2 For AC Measurements:

The ESI Model 860 ac Generator and Detector unit is recommended for use with the Model 290A bridge. If other ac generator and detector units are used, they should meet the following specifications:

1.2.1 AC Generator

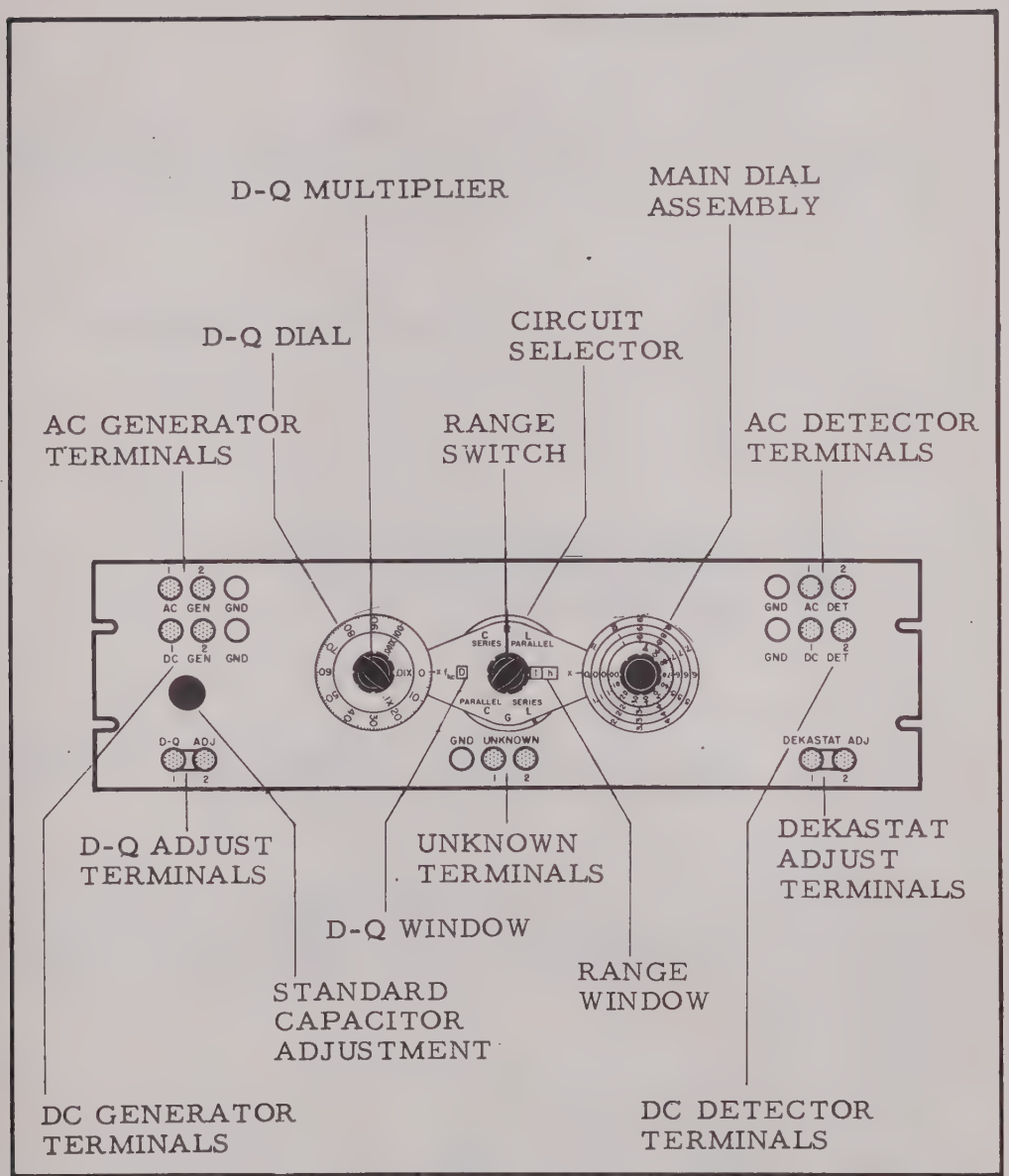
Desired characteristics:

Frequency Range: 0.1 kc to 10 kc
Output Voltage: 0 to 20 volts open circuit
Series Protective Resistor: 100 ohms or more
Isolation: Capacitance of secondary to ground less than 30 pf
Direct capacitance secondary to primary less than 0.2 pf.

1.2.2 AC Detector

Desired characteristics:

Sensitivity: 20 microvolts
Input Impedance: 500K ohms
Harmonic Suppression: 30db by 2nd harmonic



MODEL 290A PANEL CONTROLS

2. CONTROLS

2.1 Circuit Selector: The large center dial selects the bridge circuit and connects the appropriate generator and detector.

Circuit		Measurement	Generator and Detector
1.	C_s	Series Capacitance	ac 860A
2.	R_s	Resistance	dc 840
3.	L_p	Parallel Inductance	ac 860A
4.	L_s	Series Inductance	ac 860A
5.	G_s	Conductance	dc 840
6.	C_p	Parallel Capacitance	ac 860A

The circuit in use is indicated by the mark at the edge of the selector switch. The electrical measurement unit is indicated in the right half of the right-hand window. For L or C measurements, the left-hand window shows whether the dissipation factor (D) or the storage factor (Q) is being measured.

2.2 Range Switch: The black center knob selects any of seven multipliers ranging from 10^{-4} to 100. The multiplier in use appears in the left half of the right-hand window.

2.3 Main Dial Assembly: The right-hand DEKASTAT dial reading times the range multiplier reading gives the value of resistance, conductance, inductance, or capacitance being measured.

2.4 D-Q Multiplier: The left-hand black knob selects the D-Q multiplier. The multiplying factor in use appears at the left of the D or Q value.

2.5 D-Q Dial: The reading of the large left-hand dial, times the D-Q multiplier reading, times the frequency in kilocycles gives the value of D or Q.

2.6 Unknown Terminals: The unknown component is connected to the two black terminals under the center dials. An adjacent metal ground terminal is provided for a shield connection.

2.7 Generator Terminals: The upper left-hand terminals are for connecting an external generator to the bridge. Separate terminals are provided for dc and ac connections. Ground terminals are provided for convenience.

2.8 Detector Terminals: The upper right-hand terminals are for connecting an external detector to the bridge. Separate terminals are provided for dc and ac connections. Ground terminals are provided for convenience.

2.9 D-Q Adjustment Terminals: The lower left-hand terminals are for attaching an external circuit element to the D-Q arm of the bridge for special measurements.

2.10 DEKASTAT Adjustment Terminals: The lower right-hand terminals are for attaching an external circuit element to the main dial DEKASTAT arm of the bridge for special measurements.

2.11 Standard Capacitor Adjustment: The left center hole cover conceals the adjusting screw for the standard capacitor. Setting this adjustment to give the correct bridge reading for an accurately known value of capacitance (0.1 μf recommended) assures a short term bridge accuracy rating improvement for all inductance and capacitance measurements.

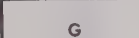
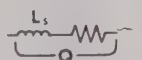
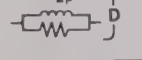
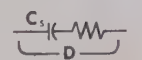
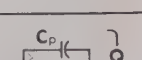
3. OPERATING INSTRUCTIONS

3.1 WHAT THE BRIDGE MEASURES

The ESI Model 290A Impedance Bridge measures resistance, conductance, inductance, and capacitance. It also measures the dissipation factor (D) and the storage factor (Q) of inductors and capacitors.

Resistance and conductance measurements are usually made with direct current because of the increased accuracy and the lack of hum pickup and stray capacitance effects. Resistance and conductance measurements can be made using ac, but they may require external reactance compensation.

Inductance and capacitance measurements are made in terms of a simple two-element circuit with the same impedance as the unknown. The bridge dials read the values of this equivalent circuit. To achieve highest measurement accuracy, an equivalent parallel circuit is used for high Q inductors and high D capacitors. An equivalent series circuit is used for low D capacitors and low Q inductors.

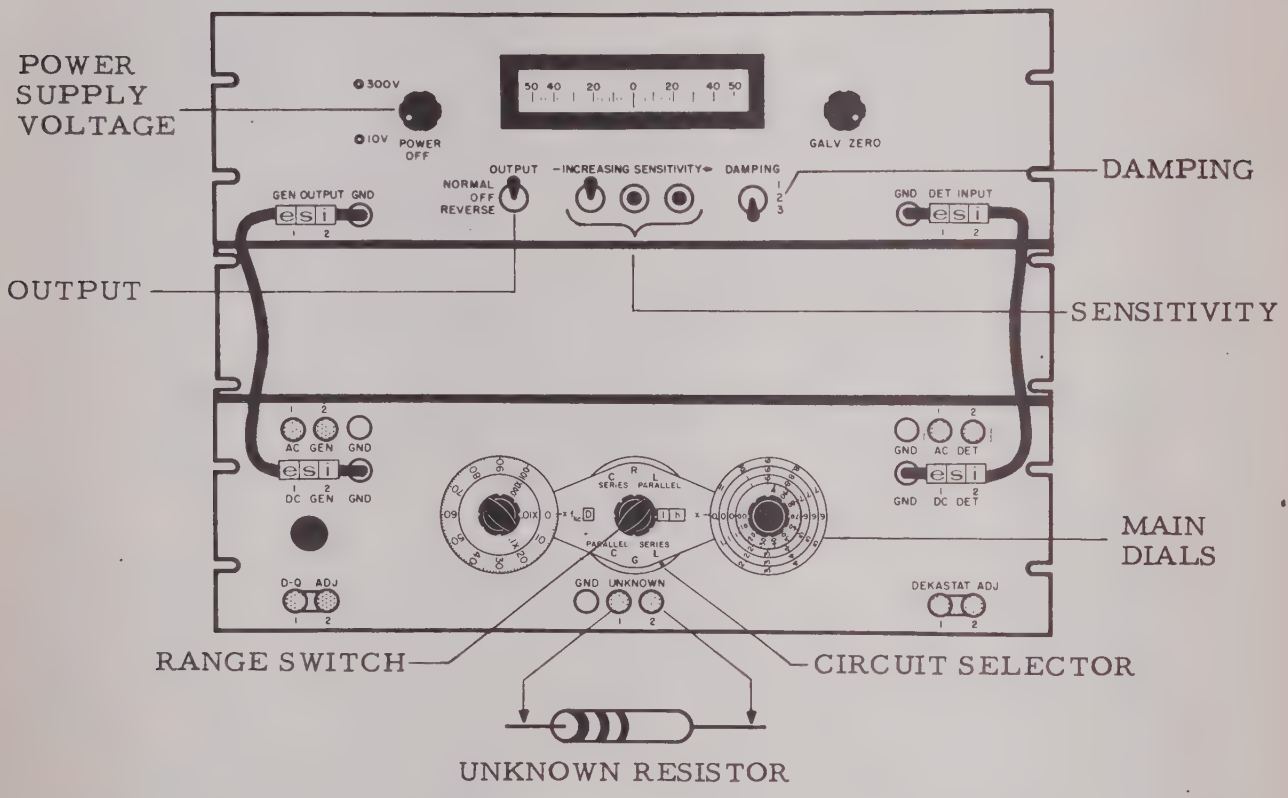
SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT	RANGES			ACCURACY △	
		MAGNITUDE	D or Q	L, R, C, G RANGE	MAGNITUDE	D or Q
R		0-1200 KILOHMS IN 7 RANGES;* 0.01 MILLIOHM PER DIAL DIV ON LOWEST R RANGE		HIGHEST	0.1% + 1 DIAL DIV	
				OTHER 5	0.05% + 1 DIAL DIV	
				LOWEST	0.1% + 1 DIAL DIV	
G		0-1200 MILLIMHOS IN 7 RANGES; 10 pmhos (1/100,000 MEGOHM) PER DIAL DIVISION ON LOWEST G RANGE		HIGHEST	0.1% + 1 DIAL DIV	
				OTHER 5	0.05% + 1 DIAL DIV	
				LOWEST	0.1% + 1 DIAL DIV	
L Series		0-1200 HENRYS IN 7 RANGES; 0.01 μh PER DIAL DIV ON LOWEST L RANGE	Q=0 TO 10.5 x f_{kc} IN 3 RANGES 0.001 x f_{kc} PER DIAL DIV ON LOWEST Q RANGE	HIGHEST	0.2% + 1 DIAL DIV + 1.2% x f_{kc}/Q	0.012 f_{kc} $(1+Q^2)$ + 0.02Q
				OTHER 5	0.1% + 1 DIAL DIV + 0.7% x f_{kc}/Q	0.007 f_{kc} $(1+Q^2)$ + 0.02Q
				LOWEST	0.2% + 1 DIAL DIV + 0.7% x f_{kc}/Q	0.007 f_{kc} $(1+Q^2)$ + 0.02Q
L Parallel		0-1200 HENRYS IN 7 RANGES; 0.01 μh PER DIAL DIV ON LOWEST L RANGE	D=0 TO 10.5 x f_{kc} IN 3 RANGES 0.001 x f_{kc} PER DIAL DIV ON LOWEST D RANGE	HIGHEST	0.2% + 1 DIAL DIV + 1.2% x D x f_{kc}	0.012 f_{kc} $(1+D^2)$ + 0.02D
				OTHER 5	0.1% + 1 DIAL DIV + 0.7% x D x f_{kc}	0.007 f_{kc} $(1+D^2)$ + 0.02D
				LOWEST	0.2% + 1 DIAL DIV + 0.7% x D x f_{kc}	0.007 f_{kc} $(1+D^2)$ + 0.02D
C Series		0-1200 MICROFARADS IN 7 RANGES; 0.01 pf PER DIAL DIV ON LOWEST C RANGE	D=0 TO 10.5 x f_{kc} IN 3 RANGES 0.001 x f_{kc} PER DIAL DIV ON LOWEST D RANGE	HIGHEST	0.2% + 1 DIAL DIV + 0.5% x D x f_{kc}	0.005 f_{kc} $(1+D^2)$ + 0.02D
				OTHER 5	0.1% + 1 DIAL DIV + 0.5% x D x f_{kc}	0.005 f_{kc} $(1+D^2)$ + 0.02D
				LOWEST	0.2% + 1 DIAL DIV + 1.0% x D x f_{kc}	0.010 f_{kc} $(1+D^2)$ + 0.02D
C Parallel		0-1200 MICROFARADS IN 7 RANGES; 0.01 pf DIAL DIV ON LOWEST C RANGE	Q=0 TO 10.5 x f_{kc} IN 3 RANGES 0.001 x f_{kc} PER DIAL DIV ON LOWEST Q RANGE	HIGHEST	0.2% + 1 DIAL DIV + 0.5% x f_{kc}/Q	0.005 f_{kc} $(1+Q^2)$ + 0.02Q
				OTHER 5	0.1% + 1 DIAL DIV + 0.5% x f_{kc}/Q	0.005 f_{kc} $(1+Q^2)$ + 0.02Q
				LOWEST	0.2% + 1 DIAL DIV + 1.0% x f_{kc}/Q	0.010 f_{kc} $(1+Q^2)$ + 0.02Q

*Equivalent resistance measurements to 100,000 megohms are possible using the conductance ranges.

△ Accuracy specifications for inductors and capacitors apply for units with reasonably high Q (low D), at frequencies near 1 kc. The nominal frequency range is 100 cycles to 10 kc, with slight accuracy derating near the limits.

3.2 RESISTORS

3.2.1 MEASURING RESISTORS *the esi way*



CONNECT DC GENERATOR AND DETECTOR

Connect the external dc generator and detector to the dc terminals. They will be connected to the correct bridge circuits by the circuit selector.

> WARNING: Limit the generator output to one watt maximum. The ESI Model 840 dc generator and detector has this protective feature built in.

CONNECT RESISTOR TO UNKNOWN TERMINALS

Make good contact with the terminals.

SET CIRCUIT SELECTOR TO R OR G

$$R \text{ in kilohms} = \frac{1}{G \text{ in millimhos}}$$

If between 0.83 ohms and 1.2 megohms, measure either RESISTANCE or CONDUCTANCE. If less than 0.83 ohms (>1.2 mho), measure RESISTANCE. If greater than 1.2 megohms (<0.83 micromhos), measure CONDUCTANCE.

3.2.1 MEASURING RESISTORS (Cont.)

SET POWER SUPPLY VOLTAGE AND DETECTOR SENSITIVITY

(See above WARNING)

When using the ESI 840 generator and detector, the voltage settings shown below will give maximum sensitivity.

WHEN USING THE 840

SET THE OUTPUT SWITCH TO "NORMAL"

SET THE LEFT HAND SENSITIVITY SWITCH UP

SET THE DAMPING SWITCH TO "3"

840 Switch Position	Resistance	Conductance
10 V	0 to 0.1 kilohms	10 to 1,200 millimho
300 V	0.1 to 1,200 kilohms	0 to 10 millimho

SET MAIN DIAL TO READ 3.00

This setting makes it easier to find the correct range.

SET RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL

This sets the range so that the value can be found with maximum resolution on the main dial.

ADJUST MAIN DIAL FOR NULL

The detector sensitivity can be increased as the null is approached. If the Galvanometer is sluggish try damping position 1 or 2. The ESI Model 840 generator and detector cannot be damaged by normal bridge use at any setting. Be careful to avoid damage if any other detector is used.

IF THE MAIN DIAL READING IS LESS THAN 1.200, USE THE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL

This takes advantage of the increased resolution near full scale of the dial.

3.2.2 THINGS TO WATCH OUT FOR

3.2.2.1 HIGH RESISTANCE MEASUREMENTS

Care must be taken to avoid leakage resistance across the unit being measured. If an electronic null detector is being used it may be affected by ac hum picked up by the leads.

3.2.2.2 LOW RESISTANCE MEASUREMENTS

On the low resistance ranges the lead resistance in the unknown arm becomes significant. A correction for this resistance can be made as follows:

1. Short the test leads together at the point that they are to be connected to the unknown resistor and measure this "ZERO RESISTANCE".

2. Connect the test leads to the unknown resistor and measure the "RESISTANCE READING".

3. The "RESISTANCE VALUE" of the unknown resistor is then the "RESISTANCE READING" minus the "ZERO RESISTANCE".

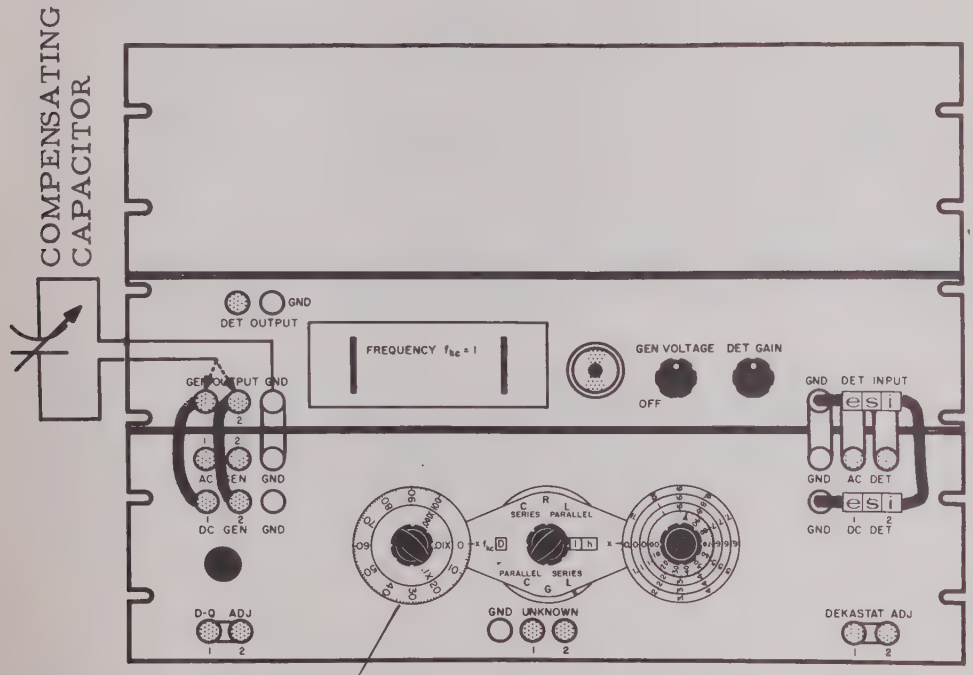
4. If the unknown resistance is to be connected directly to the terminals, the "ZERO RESISTANCE" reading can be taken by connecting a piece of heavy copper wire between the unknown resistance terminals. (#14 AWG copper wire has a resistance of about 0.00025 ohm/inch.)

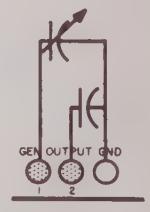
Sometimes thermal voltages are generated at connections and these can lead to erroneous balances of the bridge. If this condition is suspected, balance the bridge and then set the output switch to "reverse". If this results in a different galvanometer reading, change the main dial DEKASTAT® setting until the galvanometer reads the same for both output polarities. This cancels the effect of the thermal voltages.

3.2.3 MEASURING AC RESISTANCE *the esi way*

For greatest accuracy resistors should always be measured with dc. The accuracy of ac measurement will be 0.3% for one kilocycle and below over the range from one ohm to one megohm.

The indicated connections for the phase correction capacitor compensate for series inductance or parallel capacitance. It is impossible to seperate the correction for the unknown from that for the rest of the bridge circuit. If large reactances are involved the circuit should be measured as a capacitance or inductance and the resistance calculated.





NOTE:
If the phase correction is small it may be convenient to connect a fixed capacitor to one terminal and a variable one to the other.

REMOVE THE AC GENERATOR CONNECTING STRAPS	The ac detector straps need not be removed
CONNECT THE BRIDGE DC GENERATOR AND DETECTOR TERMINALS TO THE AC GENERATOR AND DETECTOR	Short lengths of open-wire leads for the generator will minimize errors
SET THE BRIDGE ON THE R OR G RANGE	This connects the desired bridge circuit
TRY TO BALANCE THE BRIDGE AS WITH DC	Usually the eye will not completely open, thus indicating uncompensated phase shift

CONNECT A VARIABLE CAPACITOR FROM GROUND TO ONE OF THE GENERATOR TERMINALS AND TRY TO OBTAIN A NULL WITH IT AND THE MAIN DIALS.

Connecting the capacitor from ground to either generator terminal permits compensation for some of the possible circuits of the unknown.

IF A NULL CANNOT BE REACHED, CONNECT THE VARIABLE CAPACITOR BETWEEN THE OTHER GENERATOR TERMINAL AND GROUND. A NULL SHOULD BE OBTAINABLE WITH ONE CONNECTION OR THE OTHER.

This permits balance over the remaining possible circuit combinations.

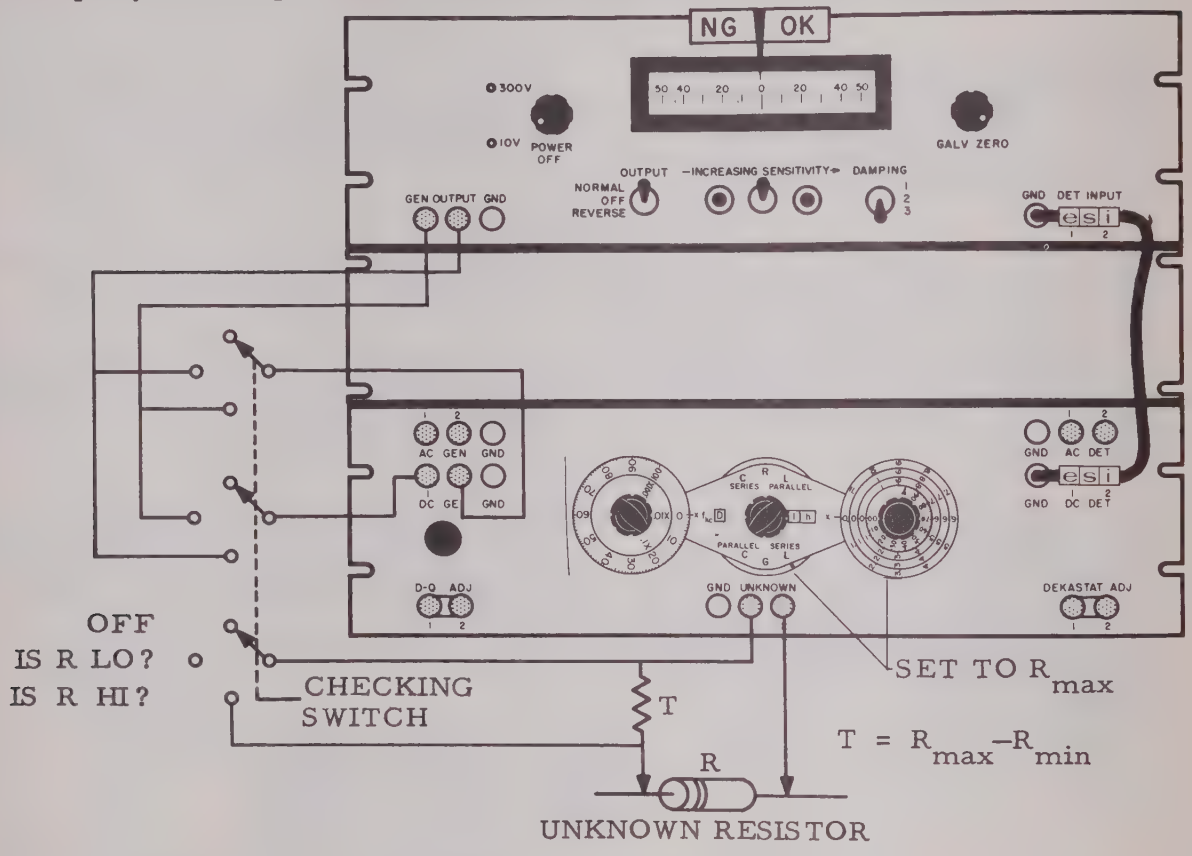
If a non linear element is being measured by ac a null balance may not be possible because the bridge will not be in balance at all parts of the cycle.

THE "RESISTANCE" VALUE AS READ WILL BE CORRECT FOR EQUIVALENT CIRCUITS CONSISTING OF A RESISTOR AND CAPACITOR IN PARALLEL OR A RESISTOR AND INDUCTOR IN SERIES.

R and G accuracy will be 0.3% or better for resistors between 1 ohm and 1 megohm at a frequency of 1 kc or less.

3.2.4 RESISTANCE LIMITS CHECKING *the esi way*

For rapidly checking resistance values between two tolerance limits.



3.2.4.1 BASIC INSTRUCTIONS

SET THE CIRCUIT SELECTOR TO R OR G. SET THE RANGE SWITCH AND MAIN DIAL DEKASTAT® TO THE UPPER RESISTANCE LIMIT.	These settings will allow checking both upper and lower limits.
CONNECT THE CIRCUIT AS SHOWN.	The generator reversal permits using the same direction of GALVANOMETER deflection for OK with both the upper and lower limit.
ATTACH THE PROBES TO THE UNKNOWN RESISTOR.	This completes the bridge circuit.
CHECK THE ZERO POSITION OF THE GALVANOMETER POINTER.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial.

3.2.4.1 RESISTANCE LIMITS CHECKING (Cont.)

FIND THE OPTIMUM SENSITIVITY SETTING BY TRIAL.	The sensitivity buttons may be left in the lock position without endangering the GALVANOMETER.
SET THE CHECKING SWITCH TO "IS R LO?".	If the GALVANOMETER deflects to the right the unknown resistor is above the lower tolerance limit.
SET THE CHECKING SWITCH TO "IS R HI?".	If the GALVANOMETER deflects to the right the unknown resistor is below the upper tolerance limit.

NOTE: If the resistance tolerance is given as $\pm\Delta\%$, the value of T will be $\frac{R2\Delta}{100}$ and R_{max} will be $(1 + \frac{\Delta}{100})$ R.

3.2.4.2 CHECKING HIGH RESISTANCE:

When checking high resistances the 300 volt supply should be used. The off position of the checking switch has been provided to remove this voltage from the bridge while changing resistors.

3.2.4.3 CHECKING LOW RESISTANCE:

When checking low resistances the probe resistance R_o must be taken into account. It can be measured by shorting the probes. The bridge dials should be set to read $R_{max} + R_o$.

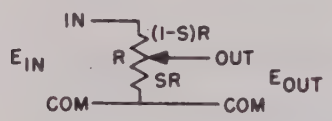
RESISTANCE LIMITS CHECKING

IF
$R_{MIN} < R < R_{MAX}$
AND IF
$T = R_{MAX} - R_{MIN}$
THEN
$(R_{MEAS}) < R_{MAX}$ Only if $R < R_{MAX}$
$(R_{MEAS} + T) > R_{MAX}$ Only if $R > R_{MIN}$

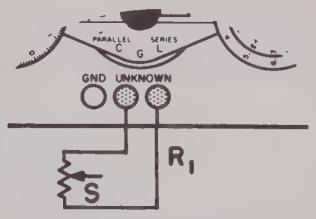
IF
$R(1+\Delta) = R_{MAX}$
$R(1-\Delta) = R_{MIN}$
THEN
$T = R2\Delta$

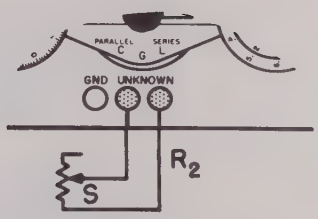
3.2.5 VOLTAGE DIVIDER CHECKING *the esi way*

3.2.5.1 SIMPLE TAPPED RESISTOR



$E_{OUT} = SE_{IN}$

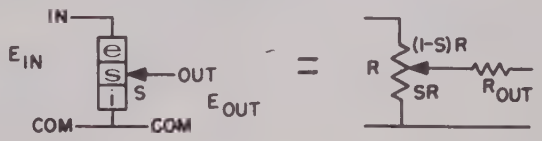




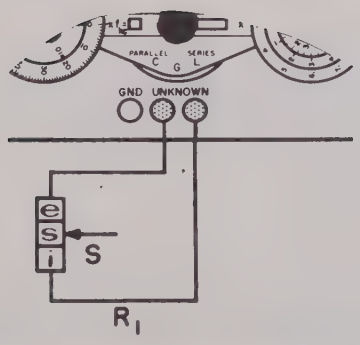
1. Follow the instructions for RESISTANCE measurement (3.2).
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Calculate the divider setting S.

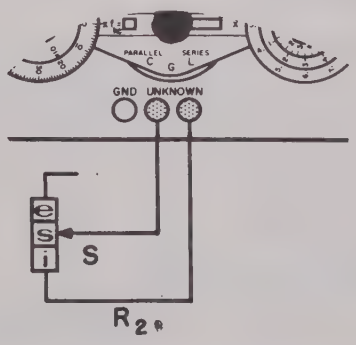
$$S = \frac{R_2}{R_1}$$

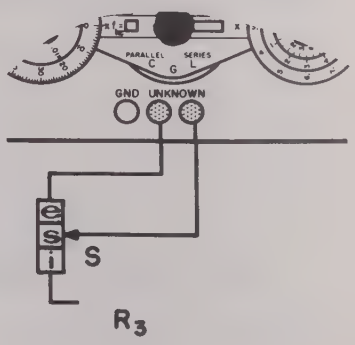
3.2.5.2 KELVIN VARLEY and other voltage divider types which may have equivalent resistance in the output lead.



$E_{OUT} = SE_{IN}$





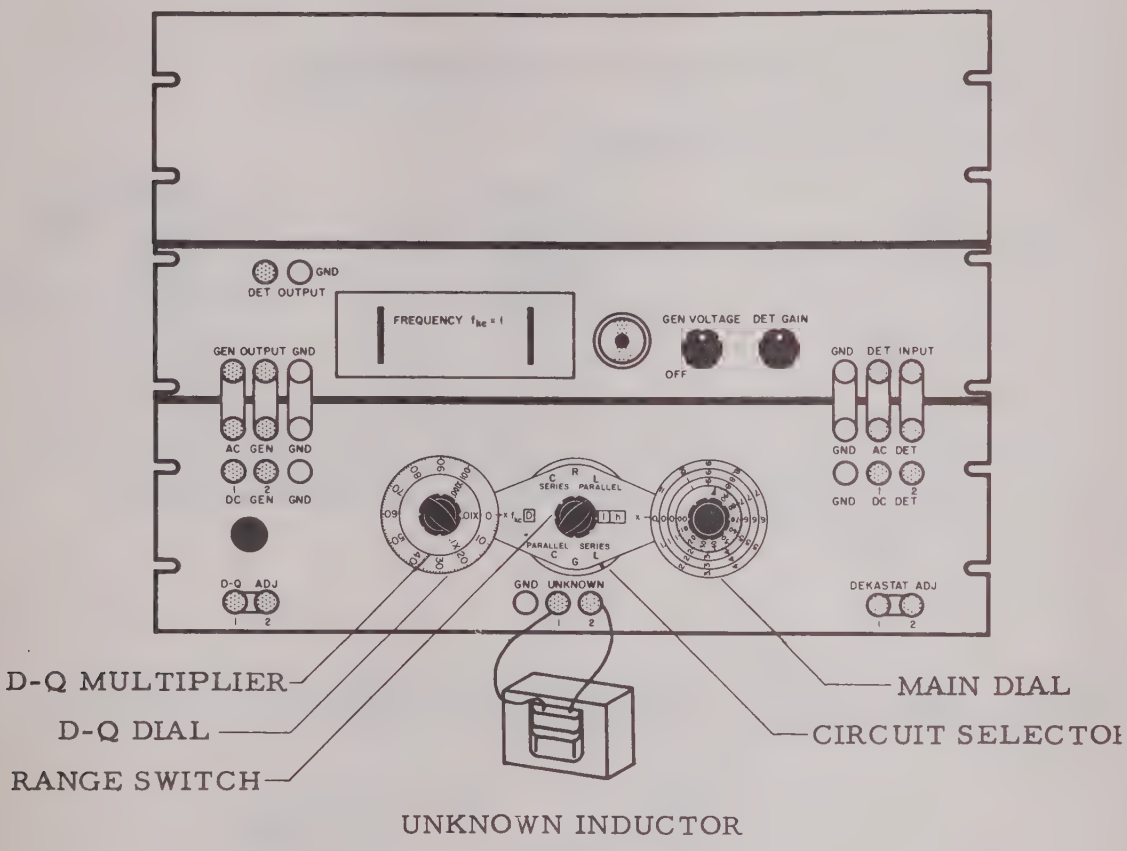


1. Follow the instructions for RESISTANCE measurement (3.2)
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Measure R_3 between the input and output terminals.
5. Calculate the divider setting S.

$$S = \frac{1}{2} + \frac{R_2 - R_3}{2R_1}$$

3.3 INDUCTORS

3.3.1 MEASURING INDUCTORS *the esi way*



OPERATING INSTRUCTIONS

CONNECT AC GENERATOR AND DETECTOR

Connect the external generator and detector to the ac terminals. They will then be connected to the correct bridge circuits by the circuit selector.

> WARNING: Limit the generator output to one watt maximum. The ESI Model 860A ac generator and detector has this protective feature built in.

CONNECT INDUCTOR TO UNKNOWN TERMINALS

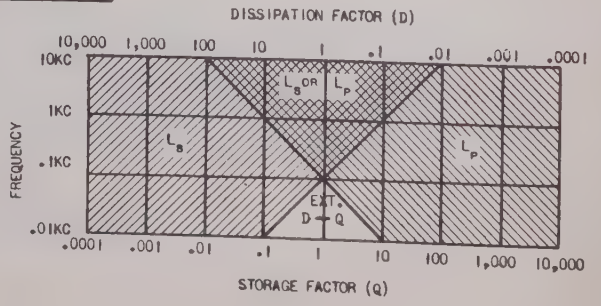
Make good contact with the terminals.

SET CIRCUIT SELECTOR TO L_p OR L_s

At 1 kc:

Use L_p for Q greater than 0.1

Use L_s for Q lower than 10



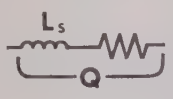
SET GENERATOR VOLTAGE AND DETECTOR GAIN (See above WARNING)	For 860A generator-detector unit, set generator voltage control and detector gain control with dots up.
SET MAIN DIAL TO READ 3.00 SET D-Q MULTIPLIER TO .1x SET D-Q DIAL TO: 0, IF BRIDGE MEASURES D, OR 100, IF BRIDGE MEASURES Q	These settings make it easier to find the correct range.
SET RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial.
ADJUST MAIN DIAL AND D-Q DIAL ALTERNATELY FOR NULL	The broad sensitivity of the ESI 860A detector unit makes sensitivity adjustment unnecessary for most measurements.
IF THE MAIN DIAL READING IS LESS THAN 1.200, USE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL IF D-Q DIAL READING IS LESS THAN 10, USE NEXT LOWER SETTING OF D-Q MULTIPLIER AND READJUST D-Q DIAL FOR NULL	This takes advantage of the increased resolution near full scale of the dials.

SEE NEXT PAGE

3.3.2 SERIES AND PARALLEL INDUCTANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of either an inductance and resistance connected in series or a different inductance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. For values of Q less than 100 the series and parallel inductances differ measurably (by more than 0.01%).

WHEN THE BRIDGE MEASURES SERIES INDUCTANCE, L_s:



L_s = (range switch setting) x (main dial reading)

Q = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$D = \frac{1}{Q}$

$R_s = \frac{1}{Q} \times 2\pi f L_s$

$Z = 2\pi f L_s (\frac{1}{Q} + j)$

Q and D in per unit
R_s in kilohms
f in kc
L_s in henrys
$j = \sqrt{-1}$
Z in kilohms

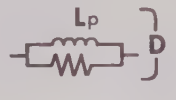
To calculate the equivalent parallel circuit:

The Q of the equivalent parallel circuit always equals the Q of the equivalent series circuit. The same is true of D.

$L_p = (1 + \frac{1}{Q^2}) \times L_s$

$R_p = Q \times 2\pi f L_p$

WHEN THE BRIDGE MEASURES PARALLEL INDUCTANCE, L_p:



L_p = (range switch setting) x (main dial reading)

D = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$Q = \frac{1}{D}$

$R_p = \frac{1}{D} \times 2\pi f L_p$

$Z = \frac{2\pi f L_p (D+j)}{D^2 + 1}$

D and Q in per unit
R_p in kilohms
f in kc
L_p in henrys
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent series circuit:

The D of the equivalent series circuit always equals the D of the equivalent parallel circuit. The same is true of Q.

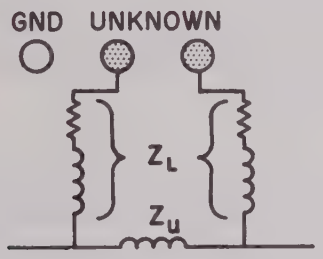
$L_s = \frac{1}{1 + D^2} \times L_p$

$R_s = D \times 2\pi f L_s$

3.3.3 THINGS TO WATCH OUT FOR

3.3.3.1 LOW INDUCTANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown inductor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u - Impedance of unknown inductor

Z_L - Impedance of leads

For greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

3.3.3.2 HIGH INDUCTANCE MEASUREMENTS

In making high inductance measurements, there are two things to watch out for:

1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

To minimize both effects keep your hands as far as possible from the inductor measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the center terminal should be shielded. See section 3.4.6 "Extended Leads".

Care should be taken to avoid coupling stray magnetic fields into the inductor being measured.

The D and Q readings on the highest L range will be in error as indicated in the specifications because of the residual capacitance of the range resistor. If accurate D or Q readings are needed the next lowest L range can be used. The L readings on the high range are accurate.

3.3.4 INDUCTANCE MEASUREMENTS WITH DC

3.3.4.1 WHEN TO USE DC

Iron core inductors are sensitive to both ac and dc current variations. Quantitative measurements of these effects can be made with the bridge.

3.3.4.2 THINGS TO WATCH OUT FOR

A. GENERAL PRECAUTIONS

Stray ac pickup may change sensitive components being measured or may give erroneous null detector readings.

The ac impedance of the dc external circuit must be greater than 2000 ohms for maximum sensitivity. If an isolating inductor is used to raise the ac impedance it may pick up stray signals or may have mutual coupling with the unknown inductor being measured. Either one may cause reading errors. Such an inductor should be well shielded magnetically and be placed to minimize its chance of interfering. For low currents isolation may be accomplished with a resistor instead of the inductor.

The parallel inductance circuit is recommended because it simplifies dc current measuring and bridge protection problems. With the series circuit the dc current divides between the bridge arms so that it is difficult to meter. The series circuit would also require a more careful analysis to avoid excessive current in any of the bridge arms.

If equivalent series inductance is required it can be easily calculated from the parallel inductance and D (See Sec. 3.3.2).

If D is too high to be read directly, an external rheostat such as the ESI Model DB-655 DEKASTAT®, connected to the D-Q ADJ terminals, can be used to extend the D range. D can be calculated by the equation:

$$D = D_{reading} + \frac{R}{1.592\, f_{kc}}$$

Where:

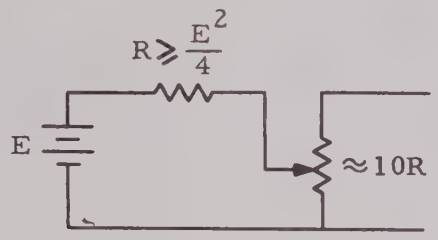
D	-	Dissipation factor of unknown
$D_{reading}$	-	Bridge D reading
R	-	External rheostat resistance in kilohms
f_{kc}	-	Operating frequency in kilocycles

B. WITH DC SUPPLIED THROUGH THE GENERATOR TERMINALS

Supplying the dc signal through the generator terminals allows more current for measuring inductors below 1.2 millihenrys. With this connection the dc current is not affected by balancing the bridge. A grounded dc generator cannot be used

because one of the detector terminals is grounded. Leakage capacitance and resistance from the dc source to ground will be across bridge arms and may cause significant errors.

Most line operated dc power supplies have high leakage capacitance to the ac line and enough dc leakage to be objectionable. An insulated, isolated battery is the recommended power supply. If a variable supply is needed the circuit shown below can be used. This circuit has a maximum output of one watt so it will not exceed the rating of any bridge element.



With the parallel inductance circuit the standard capacitor blocks the dc from all of the bridge arms except the inductor being measured and the range resistor. As a result the maximum allowable current will be limited by the range resistor. This current limit is shown in Section 3.3.4.3.

C. WITH DC SUPPLIED THROUGH THE DETECTOR TERMINALS

Supplying the dc signal through the detector terminals allows the use of higher current in measuring inductors above 1.2 millihenrys but the dc current will be influenced by the main dial DEKASTAT setting.

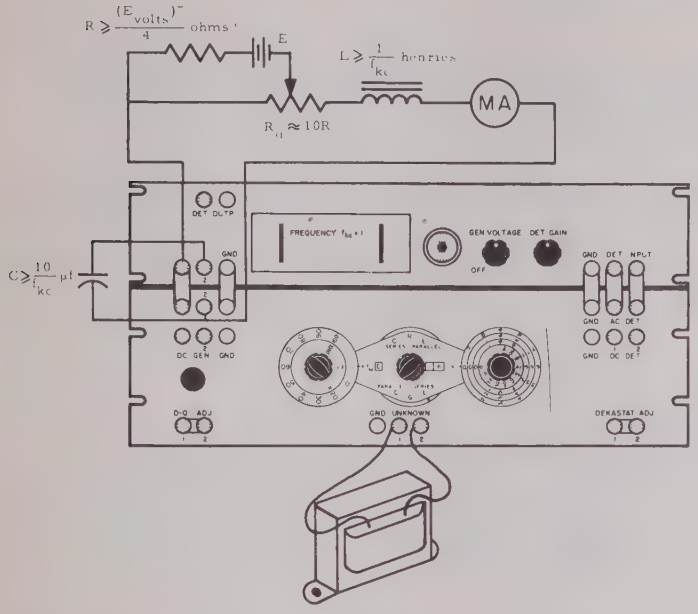
Since one of the detector terminals is normally grounded in the 860A AC GENERATOR-DETECTOR a grounded power supply can be used.

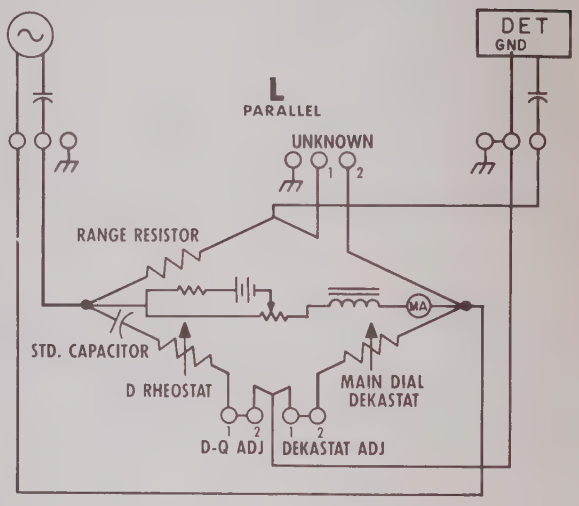
The problems resulting from stray ac pickup either from the ripple of a dc supply, capacitive coupling to power lines or the bridge generator, stray field pickup by the isolating inductor (if used), or inductive coupling to the unknown inductor, are much more serious with this connection because of the direct coupling to the detector.

In this circuit the current goes through the unknown inductor and the main dial DEKASTAT. It must be limited by the values given in Section 3.3.4.4. If more current is needed the range can be increased by one setting and the first DEKASTAT dial turned to zero. This will decrease the DEKASTAT resistance and increase its current rating. Because of the high resolution of the main dial DEKASTAT accurate measurements are possible even when the first dial is not used. By setting the first two dials to zero higher current is possible but only 100 divisions of resolution are left.

3.3.4 INDUCTANCE MEASUREMENT WITH DC (cont'd.)

3.3.4.3 For parallel inductance measurement with dc superimposed through the generator terminals.





CONNECT AS SHOWN

E - VOLTAGE SOURCE

The detector input should have an isolating capacitor. This capacitor is built into the Model 860A Generator - Detector.

R - POWER LIMITING RESISTOR

Protects the bridge, detector and unknown inductor.

L - ISOLATING INDUCTOR

Avoid ac pickup and coupling to the unknown. Prevents excessive generator loading. Not necessary if R ⩾ 100 ohms.

C - ISOLATING CAPACITOR

Keeps dc out of the Generator.

R_d - CURRENT ADJUSTING CONTROL

To set desired current.

MA - CURRENT MONITORING METER

To measure dc current.

ADJUST THE DC CURRENT AS REQUIRED

MEASURE THE INDUCTANCE

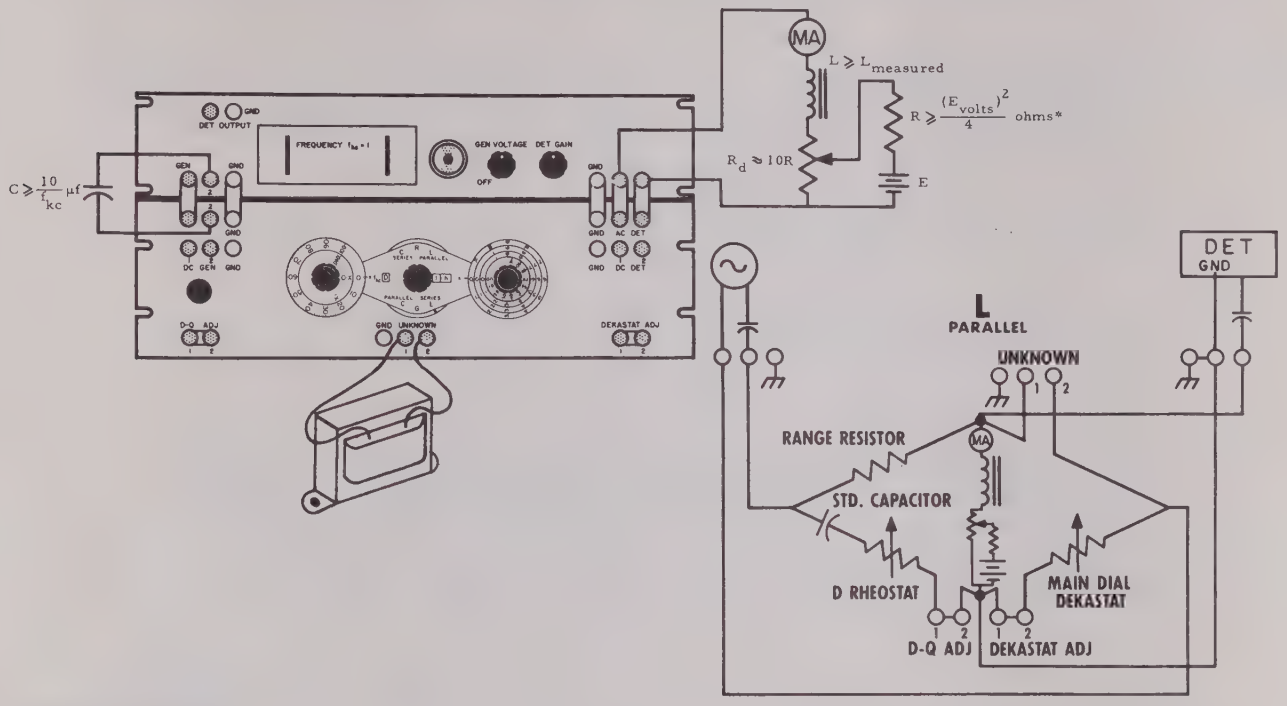
See Section 3.3

*This limits to one watt the dc power which can be supplied to the bridge thus protecting all of the bridge circuit. With care more current and voltage can be applied. The current rating of the bridge is given in the table below. These values should never be exceeded.

RANGE	UNKNOWN INDUCTANCE	MAXIMUM CURRENT
10^{-4}	0.1 μh to 1.2 mh	710 ma
10^{-3}	1 μh to 12 mh	230 ma
10^{-2}	10 μh to 120 mh	71 ma
10^{-1}	100 μh to 1.2 h	23 ma
1	1 mh to 12 h	7.1 ma
10	10 mh to 120 h	2.3 ma
100	100 mh to 1200 h	250 μa

3.3.4 INDUCTANCE MEASUREMENT WITH DC (cont'd.)

3.3.4.4 For parallel inductance measurements with dc superimposed through the detector terminals.



CONNECT AS SHOWN

E - VOLTAGE SOURCE	The detector input should have an isolating capacitor. This capacitor is built into the Model 860A Generator - Detector.
R - POWER LIMITING RESISTOR	Protects bridge, detector and unknown inductor.
L - ISOLATING INDUCTOR	Avoid ac pickup and coupling to the unknown. Prevents excessive generator loading. Not necessary if $R \geq (L_{h\text{-measured}})(f_{kc})(6)$ kilohms.
C - ISOLATING CAPACITOR	Keeps dc out of the Generator
R_d - CURRENT ADJUSTING CONTROL	To set desired current.
MA - CURRENT MONITORING METER	To measure dc current.

ADJUST THE DC CURRENT AS REQUIRED — The current will vary with the setting of the main dial.

MEASURE THE INDUCTANCE — See Section 3.3

*This limits to one watt the dc power which can be supplied to the bridge thus protecting all of the bridge circuit. With care more current and voltage can be applied. The current rating of the bridge is given in the table below. The outer dial must be set to zero to use the "2nd" dial rating. Both outer dials must be set to zero to use the "3rd" dial rating. All three decades must be set to zero to use the rheostat rating. These values should never be exceeded.

RESOLUTION	DIAL	UNKNOWN INDUCTANCE	MAXIMUM CURRENT
120,000 div	OUTER	100.0 μh to 1200 h	23 ma
10,000 div	2nd	10.0 μh to 100 h	71 ma
1,000 div	3rd	1.0 μh to 10.0 h	230 ma
105 div	RHEOSTAT	0.01 μh to 1.05 h	230 ma

**Lower limit is one division on dial which limits current on lowest range.

3.3.5 AC VOLTAGE MEASUREMENT

To measure the ac voltage applied to the unknown inductor:

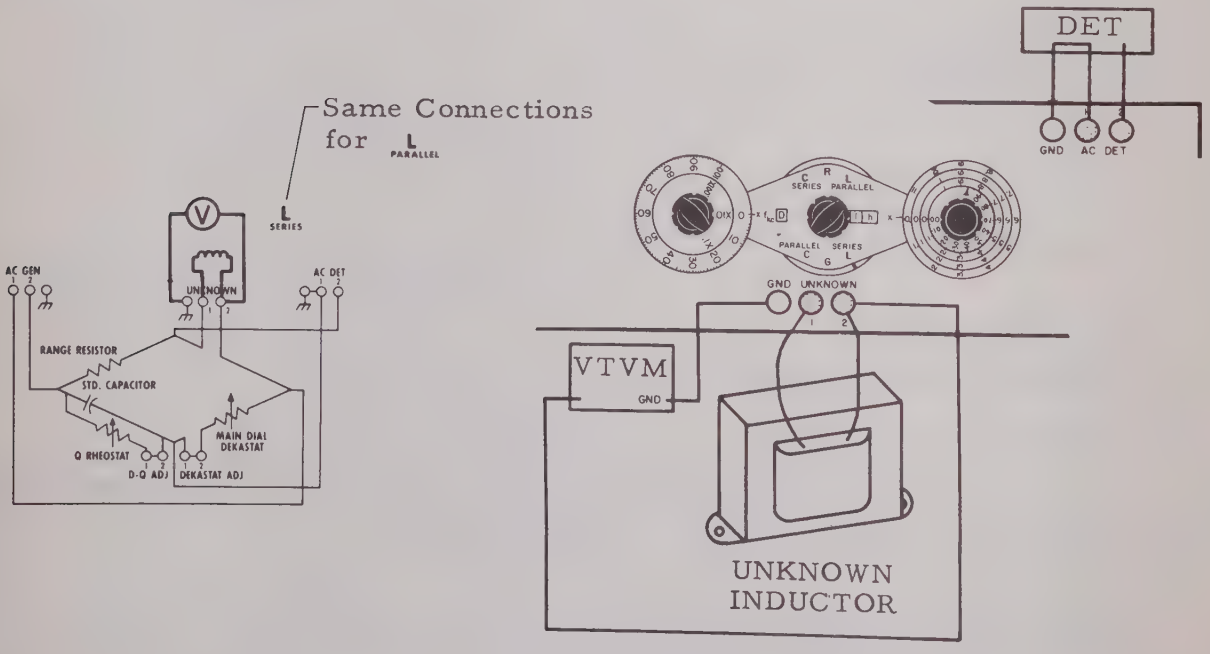
Connect ac detector No. 1 to ground. This is done internally in the 860A Generator-Detector. To prevent ground loops do not make any additional connections.

Connect the ground terminal of a high impedance ac voltmeter to a ground terminal of the bridge.

Connect the input terminal of the voltmeter to unknown terminal No. 2 of the bridge..

Balance the bridge.

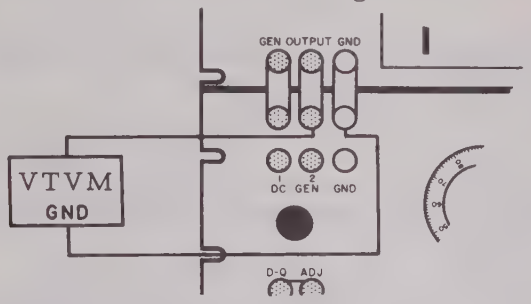
Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown inductor, but the inductor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.



3.3.6 AC CURRENT MEASUREMENT

To measure the ac current supplied to the unknown inductor:

The ac voltage across the range resistor is proportional to the ac current through the unknown. At balance this voltage is equal to the voltage across the standard capacitor arm which can be measured with a grounded voltmeter.



Connect ac detector terminal No. 1 to ground. This is done internally in the 860A Generator-Detector. To prevent ground loops do not make any additional connections.

Connect the ground terminal of a high impedance sensitive ac vacuum tube voltmeter to the ground terminal of the bridge.

Connect the input terminal of the voltmeter to AC GEN terminal No. 2 of the bridge.

Balance the bridge using either the series or parallel inductance circuit.

Read the voltmeter. The ac current in milliamperes will be equal to the voltage read (in volts) times the multiplier M from the following table.

$$I = V \times M$$

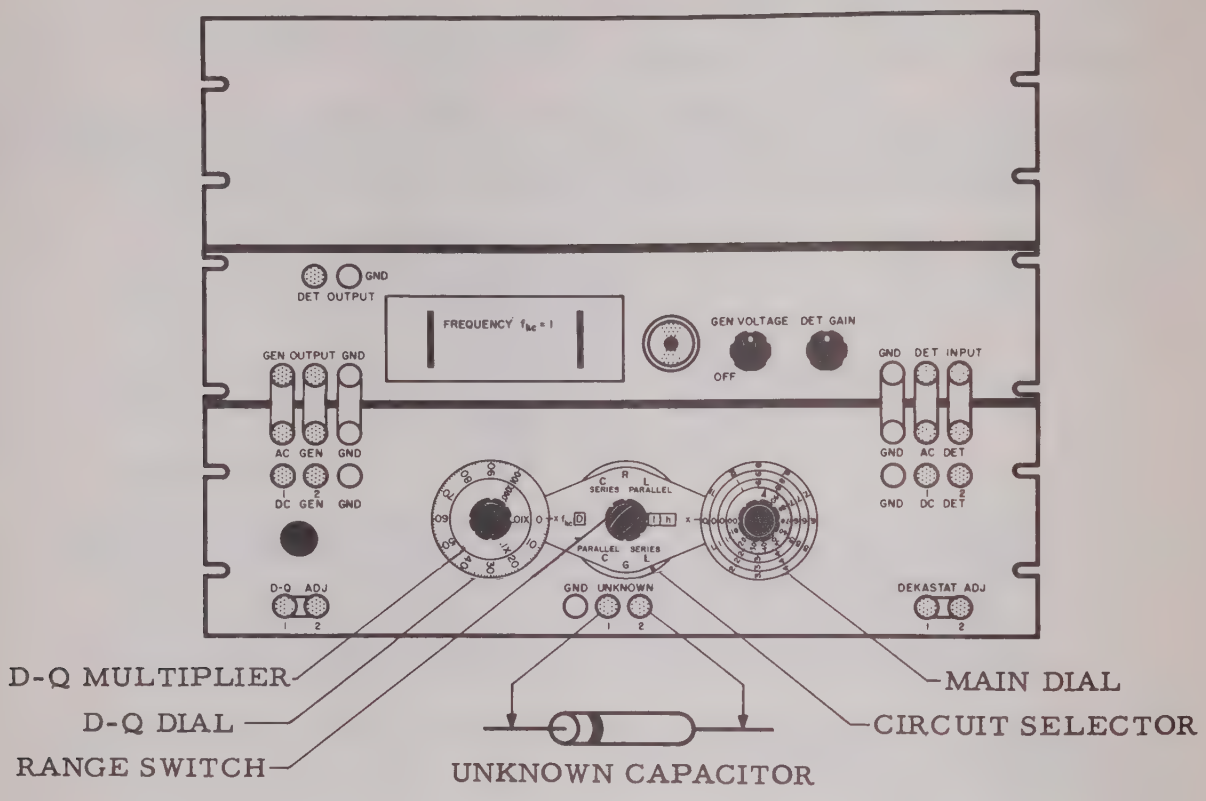
I - current in milliamperes
V - voltmeter reading in volts
M - multiplier from table

RANGE	UNKNOWN INDUCTANCE	M
10^{-4}	0.1 μh to 1.2 mh	1000
10^{-3}	1 μh to 12 mh	100
10^{-2}	10 μh to 120 mh	10
10^{-1}	100 μh to 1.2 h	1
1	1 mh to 12 h	0.1
10	10 mh to 120 h	0.01
100	100 mh to 1200 h	0.001

Remove the voltmeter and re-balance the bridge for the precise inductance measurement.

3.4 CAPACITORS

3.4.1 MEASURING CAPACITORS *the esi way*



OPERATING INSTRUCTIONS

CONNECT AC GENERATOR AND DETECTOR

Connect the external generator and detector to the ac terminals. They will then be connected to the correct bridge circuits by the circuit selector.

> WARNING: Limit the generator output to one watt maximum. The ESI Model 860A ac generator and detector has this protective feature built in

CONNECT CAPACITOR TO UN-UNKNOWN TERMINALS

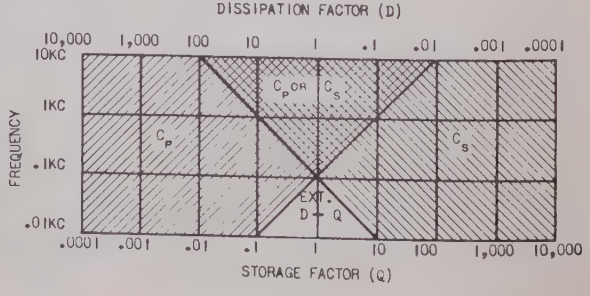
To minimize stray capacitance to ground, connect the outside foil to the left hand terminal.

SET THE CIRCUIT SELECTOR TO C_s OR C_p

At 1 kc:

Use C_p for D greater than 0.1

Use C_s for D lower than 10



Range of D and Q covered by C_s and C_p circuits.

3.4.1 MEASURING CAPACITORS (Cont.)

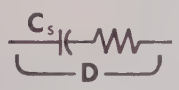
SET GENERATOR VOLTAGE AND DETECTOR GAIN (See Above WARNING)	For the 860A ac generator-detector unit, set generator voltage control and detector gain control with dots up.
SET MAIN DIAL TO READ 3.00 SET D-Q MULTIPLIER TO .1x SET D-Q DIAL TO 0, IF BRIDGE MEASURES D, OR 100, IF BRIDGE MEASURES Q	These settings make it easier to find the correct range.
SET THE RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial.
ADJUST MAIN DIAL AND D-Q DIAL ALTERNATELY FOR NULL	The broad sensitivity range of the ESI 860A detector unit makes sensitivity adjustment unnecessary for most measurements.
IF THE MAIN DIAL READING IS LESS THAN 1.200, USE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL IF D-Q DIAL READING IS LESS THAN 10, USE NEXT LOWER SETTING OF D-Q MULTIPLIER AND READJUST D-Q DIAL FOR NULL	This takes advantage of the increased resolution near full scale of the dials.

SEE NEXT PAGE

3.4.2 SERIES AND PARALLEL CAPACITANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of either a capacitance and resistance connected in series or a different capacitance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. For values of D greater than 0.01 the series and parallel capacitances differ measurably (by more than 0.01%).

WHEN THE BRIDGE MEASURES SERIES CAPACITANCE, C_s:



C_s = (range switch setting) x (main dial reading)

$D \doteq$ (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$Q = \frac{1}{D}$

$R_s = \frac{D}{2\pi f C_s}$

$Z = \frac{D - j}{2\pi f C_s}$

D and Q in per unit
R_s in kilohms
f in kc
C_s in microfarads
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent parallel circuit:

The D of the equivalent parallel circuit always equals the D of the equivalent series circuit. The same is true of Q.

$C_p = \frac{C_s}{(1 + D^2)}$

$R_p = \frac{1}{D} \times \frac{1}{2\pi f C_p}$

WHEN THE BRIDGE MEASURES PARALLEL CAPACITANCE, C_p:

C_p = (range switch setting) x (main dial reading)

Q = (D-Q multiplier) x (D-Q dial reading) x (f_{kc})

$D = \frac{1}{Q}$

$R_p = \frac{Q}{2\pi f C_p}$

$Z = \frac{\frac{1}{Q} - j}{2\pi f C_p (1 + \frac{1}{Q^2})}$

Q and D in per unit
R_p in kilohms
f in kc
C_p in microfarads
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent series circuit:

The Q of the equivalent series circuit always equals the Q of the equivalent parallel circuit. The same is true of D.

$C_s = (1 + \frac{1}{Q^2}) \times C_p$

$R_s = \frac{1}{Q} \times \frac{1}{2\pi f C_s}$

3.4.3 THINGS TO WATCH OUT FOR

3.4.3.1 LOW CAPACITANCE MEASUREMENTS

In making low capacitance measurements, there are two things to watch out for:

1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

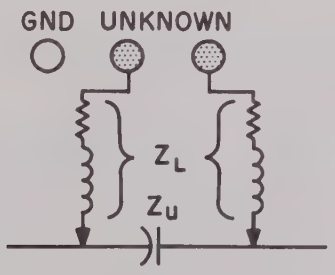
To minimize both effects, keep your hands as far as possible from the capacitor being measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the center terminal should be shielded. See section 3.4.6, "Extended Leads."

The D and Q readings on the lowest C range will be in error as indicated in the specifications because of the residual capacitance of the range resistor. If accurate D or Q readings are needed the next highest C range can be used. The C readings on the low range are accurate.

3.4.3.2 HIGH CAPACITANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown capacitor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u = Impedance of unknown capacitor

Z_L = Impedance of leads

For the greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

3.4.4 CAPACITANCE MEASUREMENT WITH DC

3.4.4.1 WHEN TO USE DC

Some capacitors need a polarizing voltage. For example, electrolytic and tantalytic capacitors can be damaged by the reverse polarity half-cycle of the test frequency. Even if the capacitors are not damaged, erroneous readings may result.

A polarizing voltage is not always needed in these measurements. If the ac voltage is kept at a very low value (typically below one-half volt), the capacitor will not be damaged, and the readings will be reasonably accurate.

Because of the high sensitivity of the Model 291A bridge, accurate measurements can be made with a very low oscillator voltage. When operating with a low oscillator voltage, be sure that the detector sensitivity is high.

3.4.4.2 THINGS TO WATCH OUT FOR

Stray ac pickup may change sensitive components being measured or may give erroneous null detector readings.

The ac impedance of the external dc circuit must be less than 200 ohms for maximum sensitivity.

The series capacitance circuit is recommended because it simplifies dc voltage protection and measuring problems. With the parallel circuit the dc voltage divides between the bridge arms so that it is difficult to meter. This also requires a more careful analysis to avoid excessive voltage across any of the bridge arms.

If equivalent parallel capacitance is required it can be easily calculated from the series capacitance and D. See section 3.4.2.

If D is too high to be read directly, an external rheostat such as the ESI Model DB-655 DEKASTAT®, connected to the D-Q ADJ terminals can be used to extend the D range. D can be calculated by the equation:

$$D = D_{reading} + \frac{R}{1.592\, f_{kc}}$$

where:

D	-	Dissipation factor of unknown capacitor
$D_{reading}$	-	D reading of bridge
R	-	External rheostat resistance in kilohms
f_{kc}	-	Operating frequency in kilocycles

3.4.4.2 THINGS TO WATCH OUT FOR (cont'd.)

If the equivalent series resistance of the capacitor being measured is much greater than the resistance of the range resistor most of the dc input voltage will appear across the unknown capacitor. If the dc resistance of the unknown capacitor is known the voltage across it will be shown by the following equation:

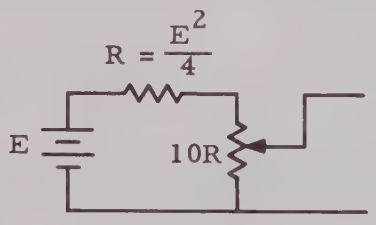
$$E_c = E_{in} \frac{R_c}{R_c + R_R}$$

where:

E_c	-	DC voltage across the unknown capacitor
E_{in}	-	DC voltage at the generator terminals
R_c	-	DC resistance of the unknown capacitor
R_R	-	Resistance of the range resistor

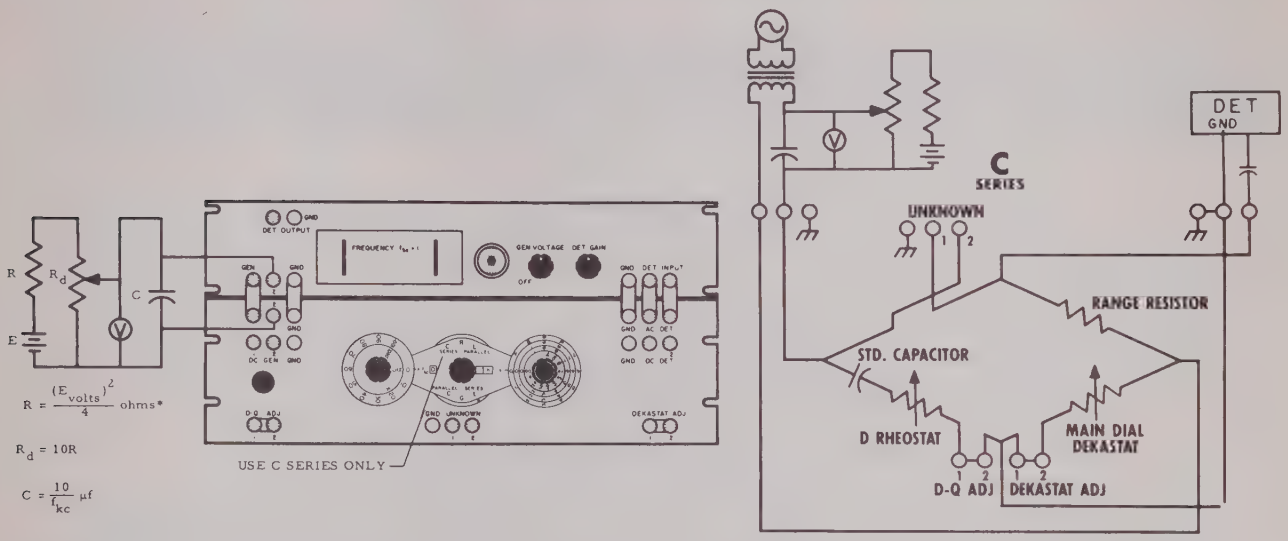
A grounded dc generator cannot be used because one of the detector terminals is grounded. Leakage capacitance and resistance from the dc source to ground will be across bridge arms and may cause significant errors.

Most line operated dc power supplies have high leakage capacitance to the ac line and enough dc leakage to be objectionable. An insulated isolated battery is the recommended power supply. If a variable supply is needed the circuit shown below can be used. This circuit has a maximum output of about one watt so it will not exceed the rating of any bridge element.



With the series inductance circuit the standard capacitor is subjected to the same dc voltage as the unknown capacitor. As a result the maximum allowable voltage must be limited to the standard capacitor rating of 300 volts.

3.4.4.3 FOR SERIES CAPACITANCE MEASUREMENTS WITH SUPERIMPOSED DC:



CONNECT THE CIRCUIT AS SHOWN	The detector input should have an isolating capacitor. This capacitor is built into the Model 860A Generator-Detector.
E - DC VOLTAGE SOURCE	Battery recommended to avoid stray pickup and leakage
R - POWER LIMITING RESISTOR $R = \frac{(E_{volts})^2}{4}$ ohms*	This protects the bridge in case the unknown terminals are shorted.
R_D - VOLTAGE ADJUSTING CONTROL	This sets the dc voltage.
CONNECT THE METER "V" IN PARALLEL WITH THE DC SUPPLY	The impedance of most meters is high enough so that they will not load the dc supply.
ADJUST THE DC VOLTAGE AS REQUIRED	For low leakage capacitors the voltage across the unknown capacitor will be equal to the voltmeter "V" reading.
MEASURE THE CAPACITANCE	See section 3.3.4.

*This limits the dc power that can be supplied to the bridge to one watt to protect all of the bridge circuit in case the unknown capacitor is accidentally shorted. The maximum dc supply should not exceed 300 volts for the protection of the standard capacitor.

3.4.5 AC VOLTAGE MEASUREMENT

To measure the ac voltage applied to the unknown capacitor:

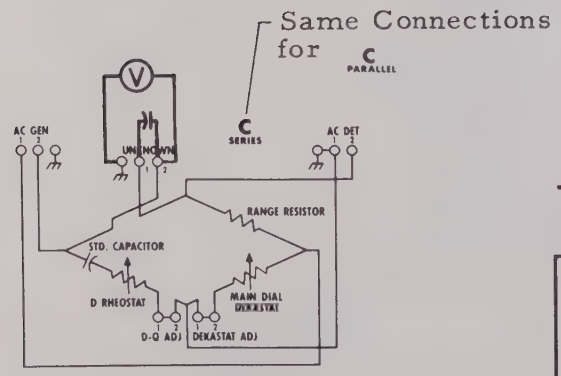
Connect ac detector terminal No. 1 to ground. This is done internally in the 860A Generator-Detector. To prevent ground loops do not make any additional connections.

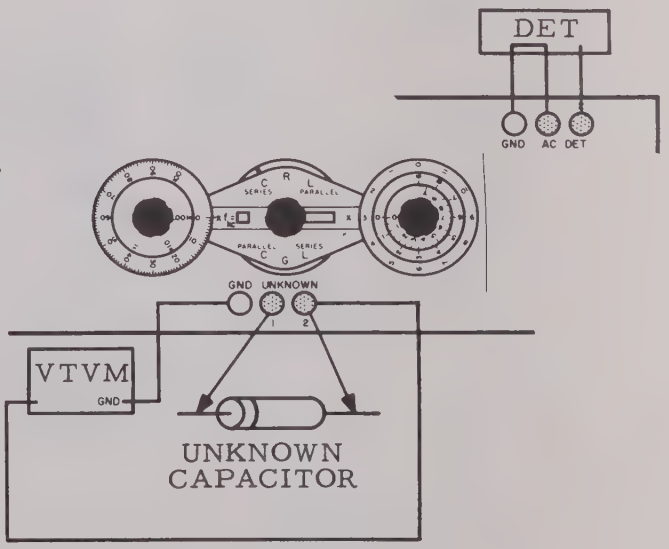
Connect the ground terminal of a high impedance ac voltmeter to the ground terminal of the bridge.

Connect the input terminal of the voltmeter to the right-hand terminal of the bridge.

Balance the bridge.

Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown capacitor, but the capacitor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.





3.4.6 EXTENDED LEADS

Sometimes it is necessary to use extended leads. This can be done easily without causing error in the measurement.

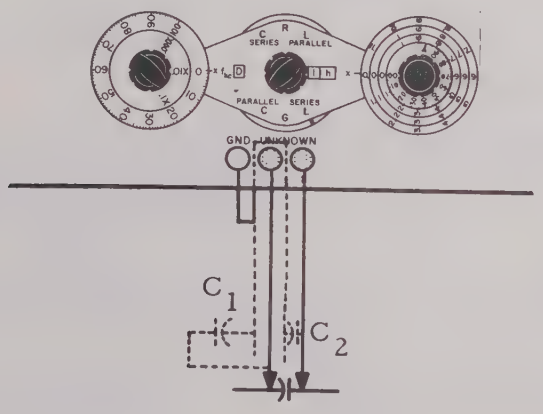
Connect a shielded lead to the center terminal.

Connect the shield of this lead to the shield terminal of the bridge.

Connect an ordinary clip lead to the right-hand terminal.

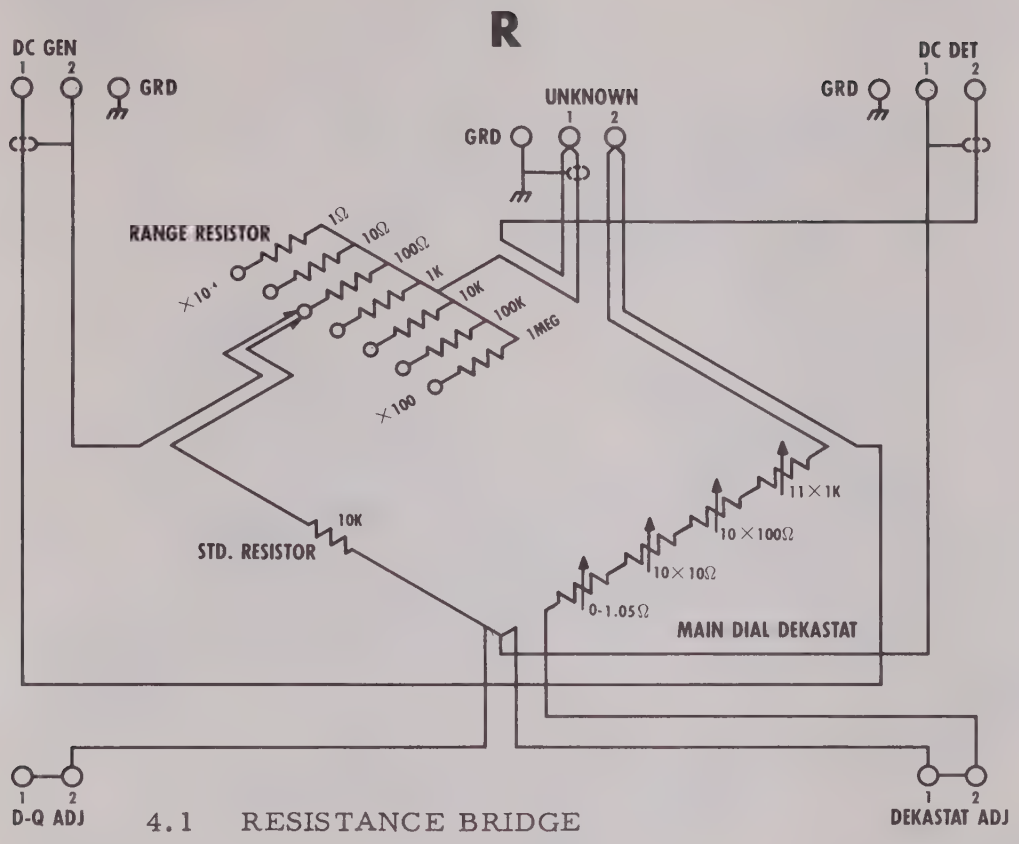
The capacitance between the shield and the center conductor is now across the detector. This keeps it from causing any error. If this stray capacitance is greater than 500 μμf, it may reduce the detector sensitivity.

The stray capacitance from the unshielded lead to ground is across the standard capacitance arm of the bridge. As the standard capacitor is 100,000 μμf, the stray capacitance will not cause significant errors unless it exceeds a few 10's of μμf.

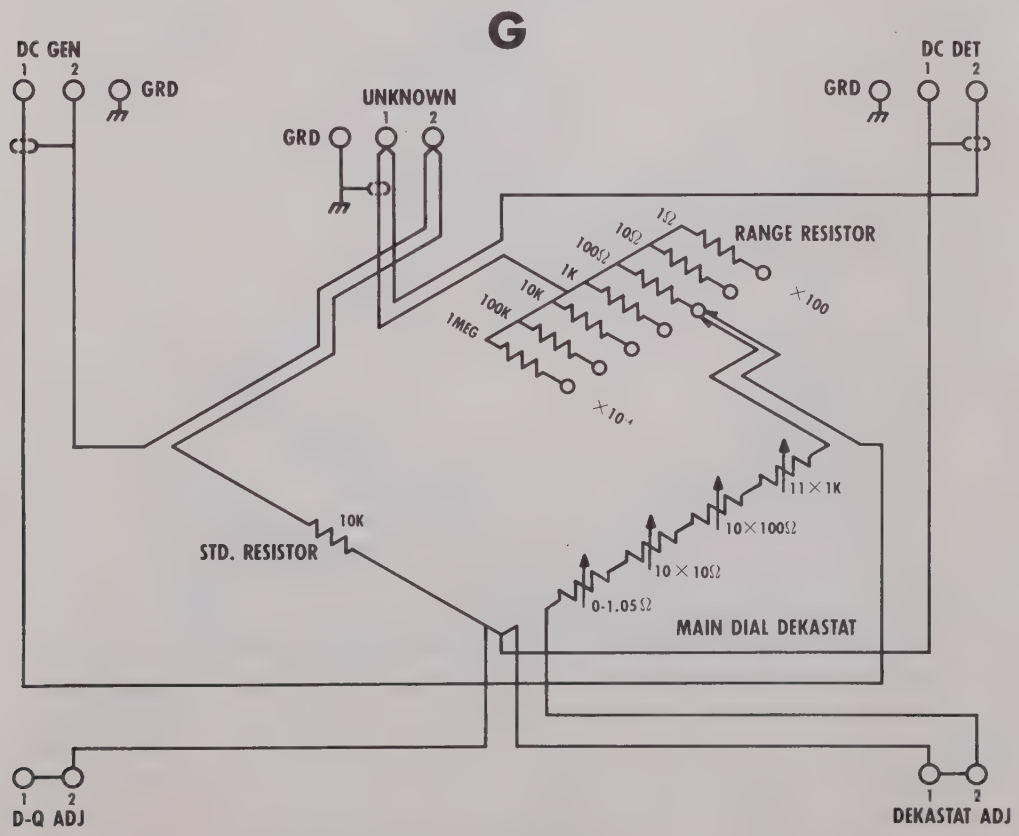


C_1: Capacitance from center conductor to ground

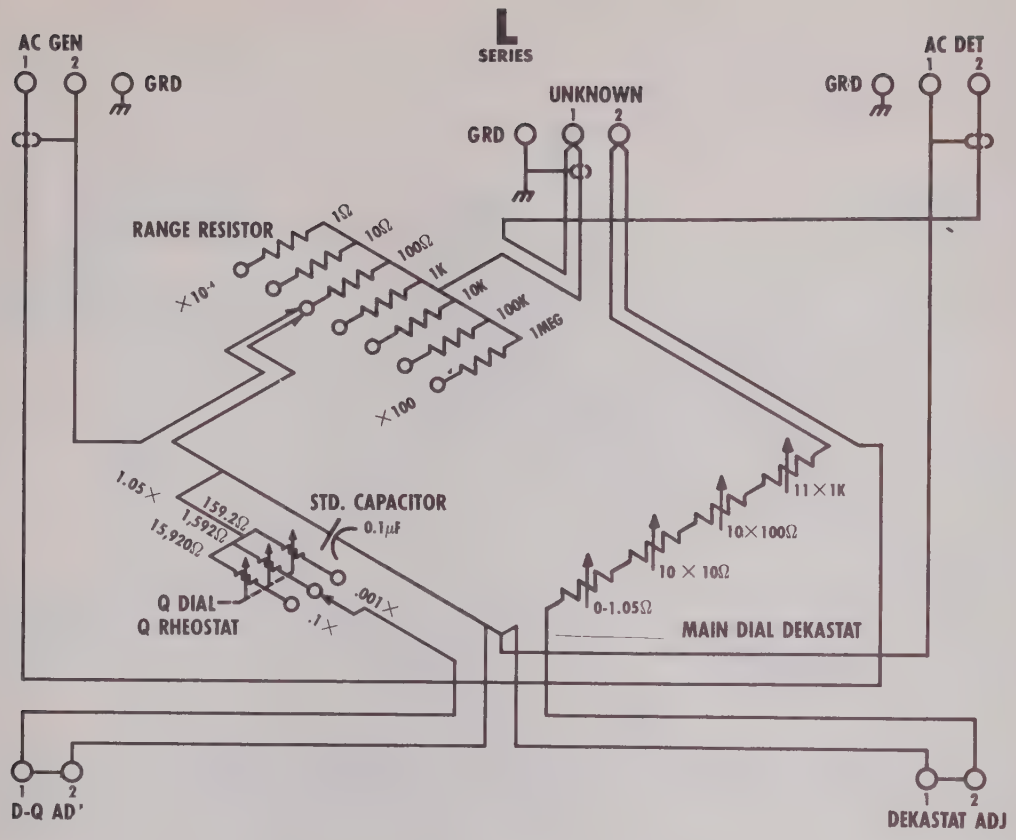
C_2: Capacitance from unshielded conductor to ground



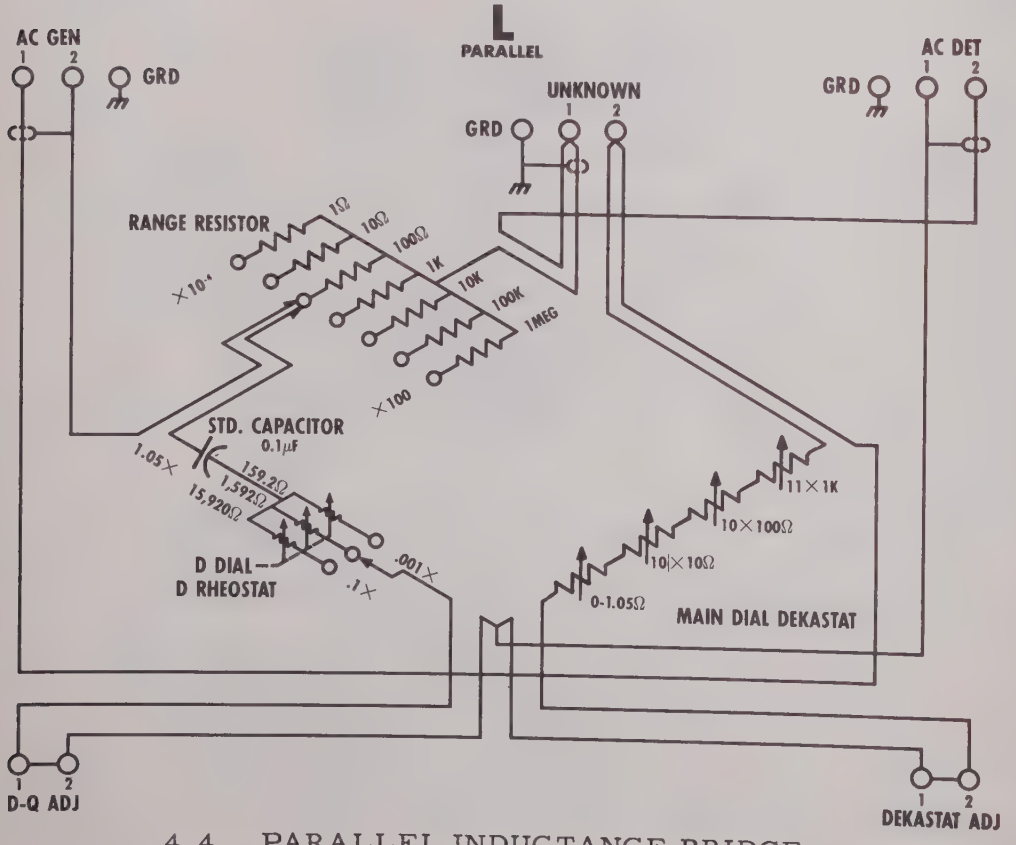
4.1 RESISTANCE BRIDGE



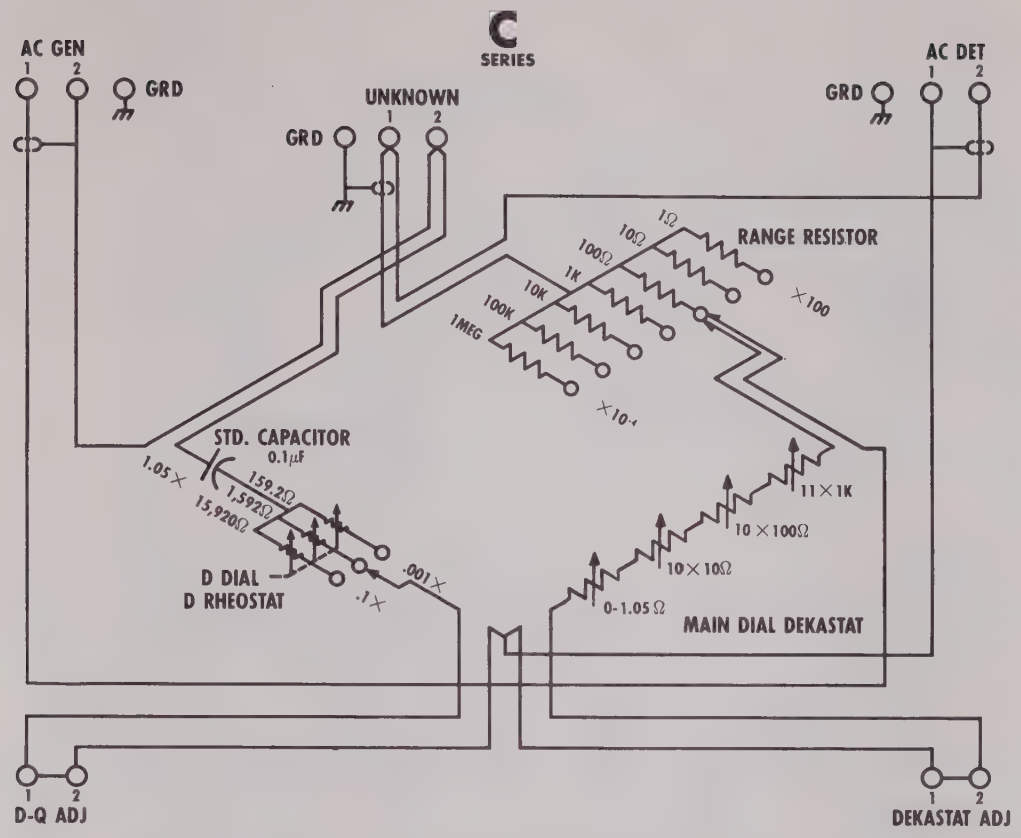
4.2 CONDUCTANCE BRIDGE



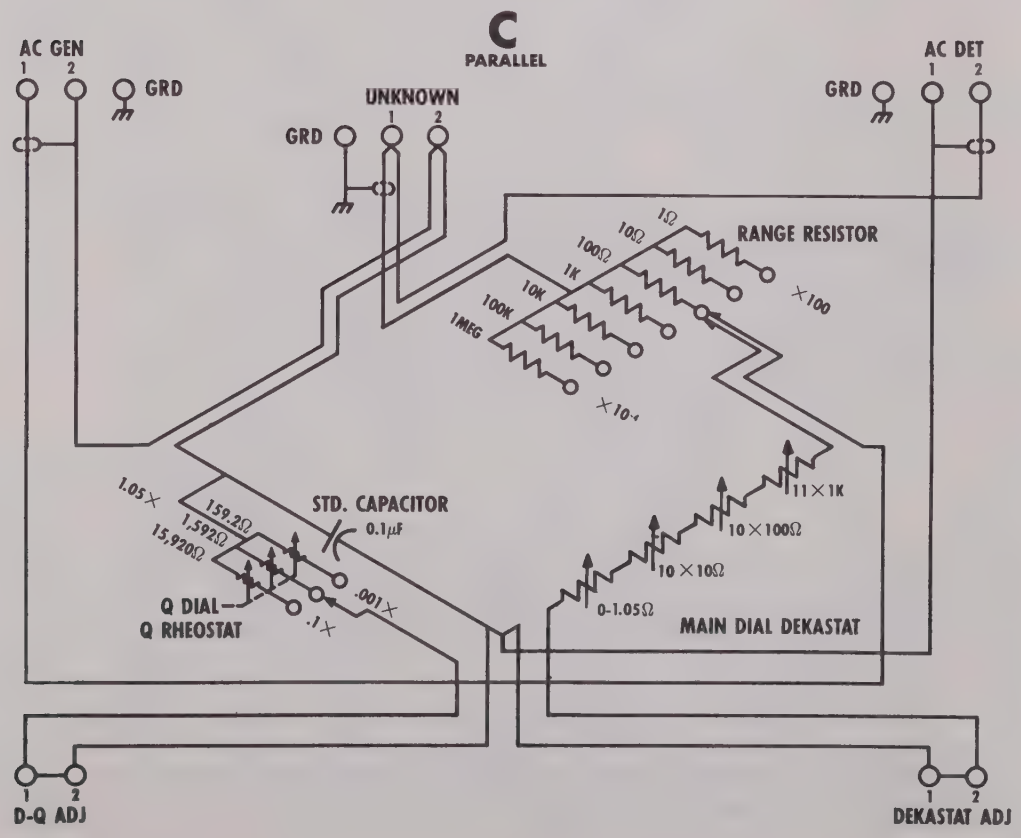
4.3 SERIES INDUCTANCE BRIDGE



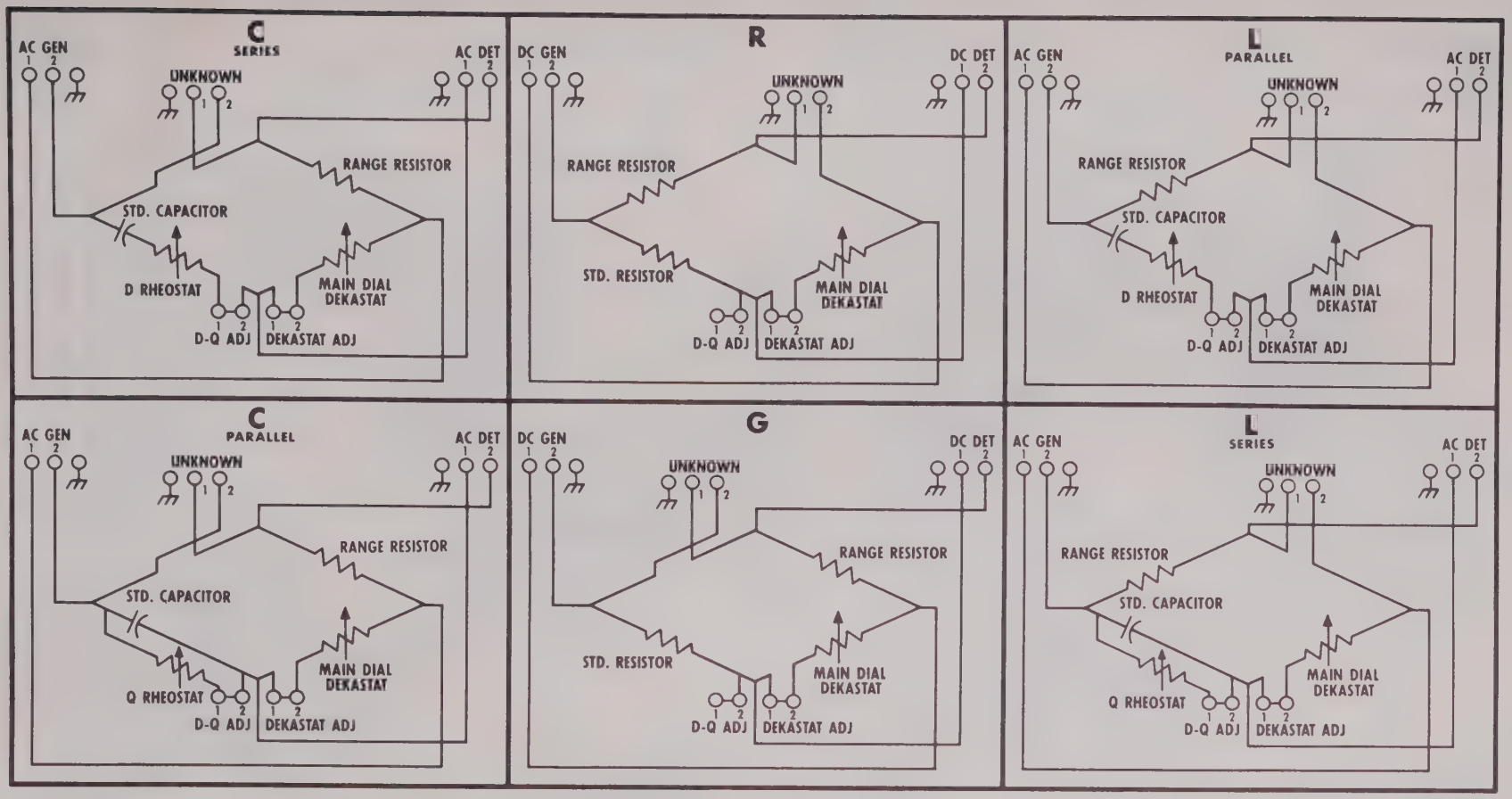
4.4 PARALLEL INDUCTANCE BRIDGE



4.5 SERIES CAPACITANCE BRIDGE



4.6 PARALLEL CAPACITANCE BRIDGE



4.7 BASIC CIRCUITS

5. BRIDGE ELEMENT VOLTAGE AND CURRENT LIMITS

RANGE RESISTORS

Safe Power limited to 1/2 watt per resistor

Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
1	0.71	710.00
10	2.30	230.00
100	7.10	71.00
1,000	23.00	23.00
10,000	71.00	7.10
100,000	230.00	2.30
1,000,000	250.00	0.25

D-Q RHEOSTATS

Safe power limited to 7 watts into total resistance

Resistance in Kilohms	Maximum Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
D-Q reading x 0.01592	166	35	210
D-Q reading x 0.1592	1,670	110	68
D-Q reading x 1.5920	16,750	350	21

STANDARD RESISTOR

Safe power limited to 1/2 watt

Resistance in Ohms	Max Voltage in Volts	Max Current in Milliamperes
10,000	71	7.1

MAIN DIAL RHEOSTAT

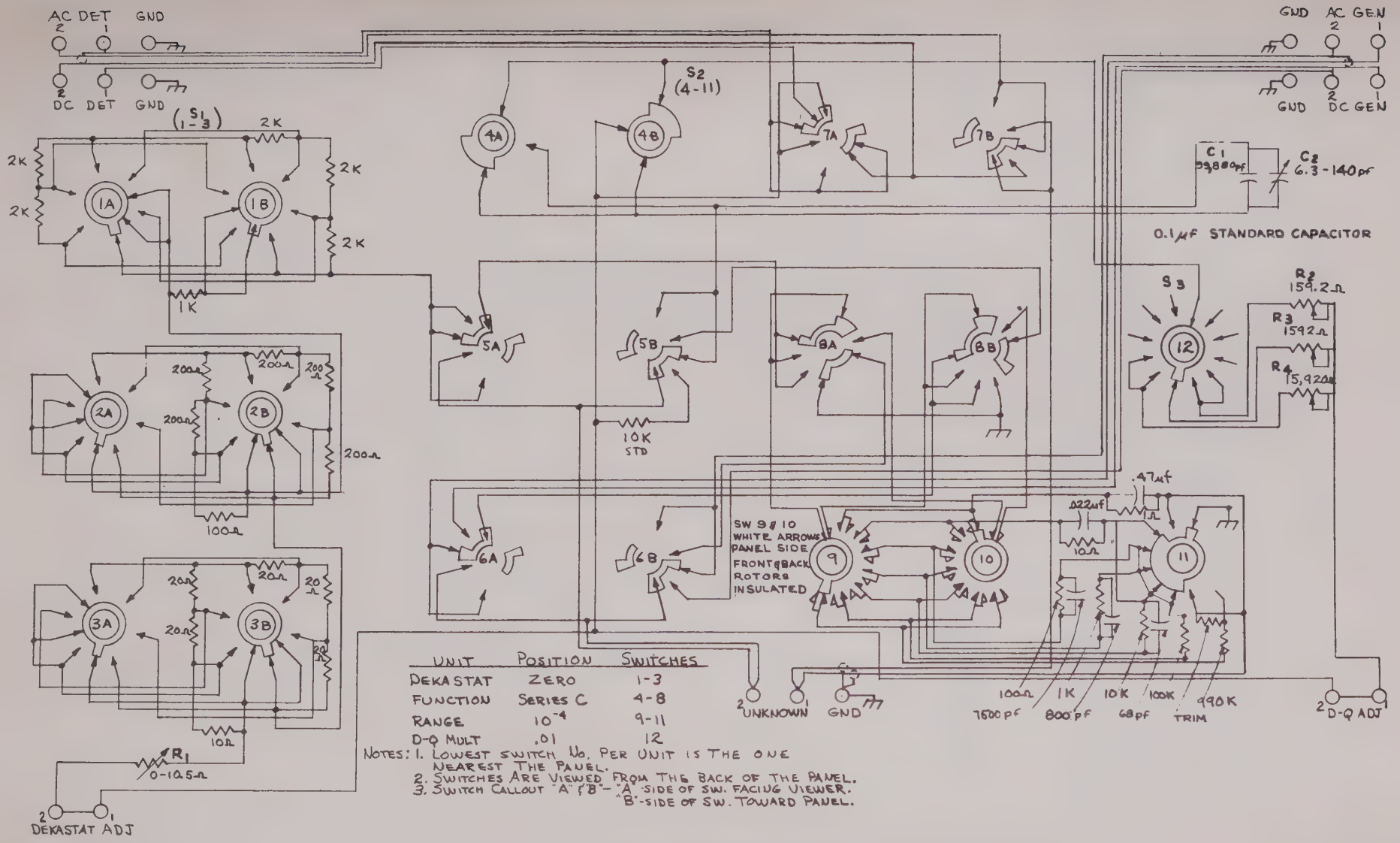
Safe power limited to 1/2 watt per step

Decade	Resistance	Max Voltage	Max Current
First	1000 Ω steps	23 Volts per step	23 ma
Second	100 Ω steps	7.1 Volts per step	71 ma
Third	10 Ω steps	2.3 Volts per step	230 ma
Rheostat	0 - 1.05 Ω	2.3 Volts at max	230 ma

6. CONVENIENT AUDIO FREQUENCY UNITS

For measurement and calculation in the audio frequency range the conventional electrical units are often inconvenient. A consistent set of units can be chosen so that the numerical values commonly encountered will be more practical while at the same time the equations used in calculations will not require any troublesome conversion constants. If either set of units listed below is followed consistently, the equations used for calculations will be unaltered. For example, E = IR holds true equally well with E in volts, I in amperes, and R in ohms; or with E in volts, I in milliamperes and R in kilohms. The 291 dials read directly in these "convenient" units.

Function	Conventional Units	Convenient Audio Frequency Units
ω	radian/sec = $2\pi f_{cps}$	kiloradian/sec = $2\pi f_{kc}$
f	cps	kc
t	second	millisecond
C	farad	microfarad
Z, R and X	ohm	kilohm
L	henry	henry
I	ampere	milliamp
E	volt	volt
P	watt	milliwatt
Q and D	per unit ratio	per unit ratio



UNIT	POSITION	SWITCHES
DEKASTAT	ZERO	1-3
FUNCTION	SERIES C	4-8
RANGE	10^{-4}	9-11
D-Q MULT	.01	12

NOTES: 1. LOWEST SWITCH No. PER UNIT IS THE ONE NEAREST THE PANEL.
2. SWITCHES ARE VIEWED FROM THE BACK OF THE PANEL.
3. SWITCH CALLOUT 'A' & 'B' – 'A' SIDE OF SW. FACING VIEWER. 'B' SIDE OF SW. TOWARD PANEL.

MODEL 290-A IMPEDANCE BRIDGE
WIRING DIAGRAM

PARTS LIST

ESI MODEL 290A

REFERENCE DESIGNATION	PART NO.	DESCRIPTION	RS*
		CAPACITORS	
C_1	4092	Capacitor, Standard	1
C_2	5277	Capacitor, Variable Air, 6.3 - 140pf	1
		RESISTORS	
R_1	3338	Potentiometer, 0 - 10.5 ohms	1
R_2	3219	Rheostat, 159.2 ohms	1
R_3	3217	Rheostat, 1592 ohms	1
R_4	3213	Rheostat, 15,920 ohms	1
		SWITCHES	
S_1**	3215	DEKASTAT Ass'y	1
S_2**	3298	Multiplier Function Ass'y	1
S_3**	3211	D-Q Rheostat Ass'y	1

* Electrical components recommended for sparing to sustain operation for 18 months.
** Includes resistors. Replace entire unit.

Universal Impedance Bridge

MODEL 291B

DC RESISTANCE AND CONDUCTANCE MEASUREMENTS

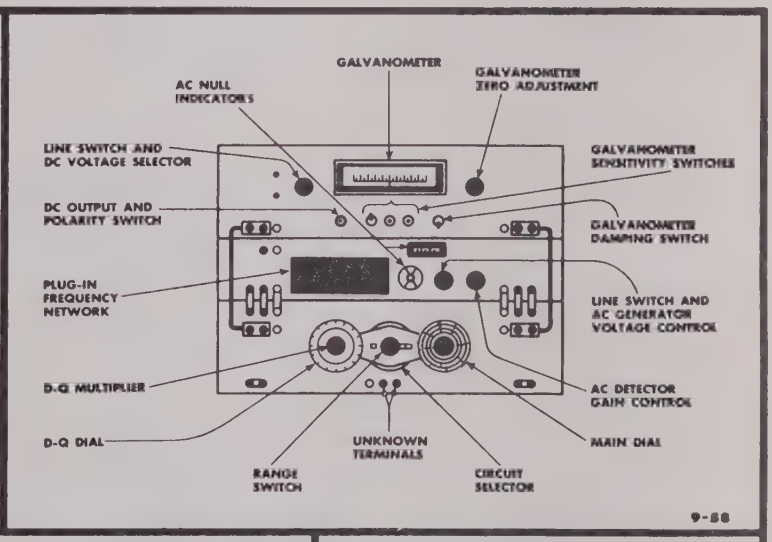
1. Set the Output and Sensitivity Switches to the Center Position (Off).
2. Set the Circuit Selector to R or G.
3. Set the DC Voltage Selector to 10 V.
4. Connect the Resistor to the Unknown Terminals.
5. Adjust the Galvanometer Zero, if necessary.
6. Set the Galvanometer Damping Switch to Position 3.
7. Turn on the lowest Sensitivity Switch. The Switch may be pressed down for momentary contact, or up for locking contact.
8. Set the DC Output Switch to Normal.
9. Set the Main Dial of the Bridge to read 3.000.
10. Adjust first the Range Switch, then the Main Dial, for minimum Galvanometer deflection. Turn on the higher Sensitivity Switches as the null is approached.
11. If the balance is beyond full scale on the highest range, change the Circuit Selector from R to G, or from G to R.
12. If the Main Dial reading at balance is less than 1.200, use the next lower setting of the Range Switch and re-adjust the Main Dial for a null.
13. If the Galvanometer response is sluggish when the highest Sensitivity Switch is on, change the Damping Switch to Position 2 or 1.
14. For increased sensitivity on high resistance measurements set the DC Voltage Selector to 300 V.
15. Return the DC Output and Sensitivity Switches to Off Position before disconnecting the Resistor.

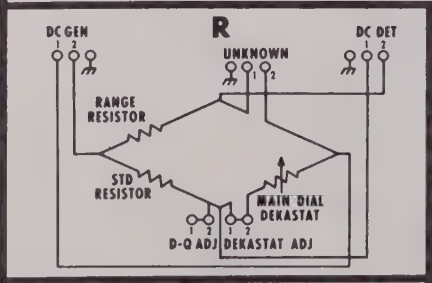
AC CAPACITANCE AND INDUCTANCE MEASUREMENTS

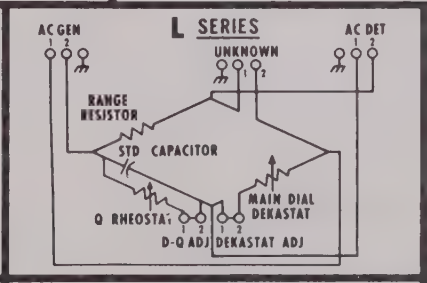
1. Set the Circuit Selector to the appropriate C or L circuit.
2. Connect the Capacitor or Inductor to the Unknown Terminals.
3. Set the Generator Voltage Control with the dot up.
4. Set the Detector Gain Control with the dot up.
5. Set the Main Dial of the Bridge to read 3.000.
6. Set the D-Q Dial to
   0, if the Bridge measures D; or
   100, if the Bridge measures Q.
7. Set the D-Q Multiplier to .1X.
8. Adjust first the Range Switch, then the Main Dial and D-Q Dial, for the widest shadow on the AC Null Indicator. Continue to adjust the Main Dial and D-Q Dial alternately to obtain the widest and sharpest possible shadow.
9. If the balance is beyond full scale on the D-Q Dial, set the Circuit Selector to the other C or L circuit, and repeat from Step 6.
10. If the Main Dial reading at balance is less than 1.200, use the next lower setting of the Range Switch and re-adjust the Main Dial for a null.
11. If the D-Q Dial reading at balance is less than 10, use the next lower setting of the D-Q Multiplier and re-adjust the D-Q Dial for a null.
12. If additional sensitivity is needed, increase the Detector Gain and/or the Generator Voltage.

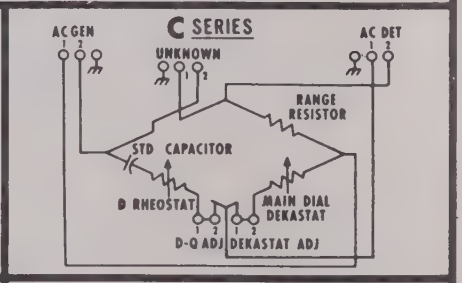
OVERLOAD PROTECTION — The bridge and its associated ac and dc detectors are protected from accidental damage by internal generator power limiting.

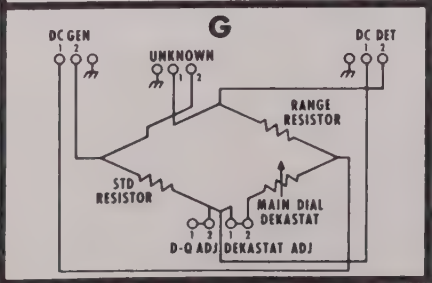
SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT	CONVERSION EQUATIONS
R	R	$G = \frac{1}{R}$
G	G	$R = \frac{1}{G}$
L Series	L_s, Q	$L_p = L_s \cdot \left(1 + \frac{1}{Q^2}\right)$ $D = \frac{1}{Q}$
L Parallel	L_p, D	$L_s = L_p \cdot \left(\frac{1}{1+D^2}\right)$ $Q = \frac{1}{D}$
C Series	C_s, D	$C_p = C_s \cdot \left(\frac{1}{1+D^2}\right)$ $Q = \frac{1}{D}$
C Parallel	C_p, Q	$C_s = C_p \cdot \left(1 + \frac{1}{Q^2}\right)$ $D = \frac{1}{Q}$

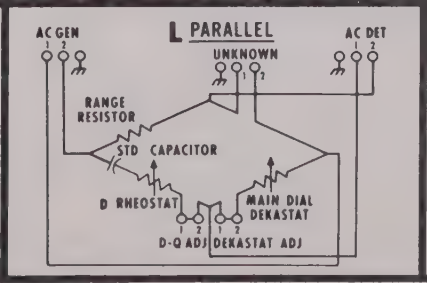


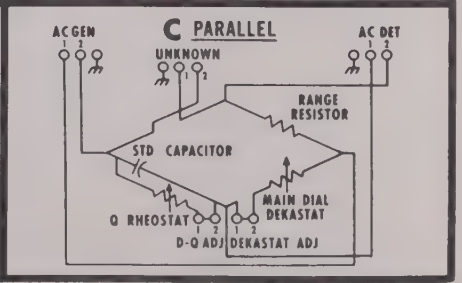












ELECTRO-SCIENTIFIC INDUSTRIES, INC. — 7524 S. W. MACADAM, PORTLAND 19, OREGON

RECOMMENDED SPARE PARTS LIST
ESI MODEL 290A UNIVERSAL IMPEDANCE BRIDGE

ITEM	PART NO.	DESCRIPTION	RS*
1.	2780	Dial Assy	1
2.	3242	Dial Assy	1
3.	4275	Dial Assy	1
4.	3332	Dial	1
5.	3333	Dial	1
6.	3346	Dial Assy	1
7.	3344	Dial Assy	1
8.	3243	Dial Assy	1
9.	1255	Knob	1
10.	1294	Cap, Binding Post	2
11.	1296	Cap, Binding Post	2
12.	1393	Binding Post	2
13.	3375	Mask	1
14.	3247	Swing Lug	1
15.	3298	Multiplier Function Assy.	1
16.	3211	D-Q Rheostat Assy	1
17.	3215	Dekastat Assy	1
18.	4092	Capacitor Std.	1
19.	1277	Washer, Shoulder	4
20.	2326	Insulator	2
21.	4148-1	Test Lead	1
22.	4148-2	Test Lead	1

Recommended Spare Parts List
Model 290A (Continued)

ITEM	PART NO.	DESCRIPTION	RS*
23.	3331	Shield Cover	1
24.	3295	Shield, Binding Post	1
25.	3347	Dust Cover	1
26.	8823	Shoulder Washer	1

*Recommending for sparing to sustain operation for 18 months.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument should be tested upon receipt. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be forwarded to us by the claim agent. We will then advise you of the disposition to be made and arrange for repair or replacement. Include model and serial number when referring to this instrument.

WARRANTY

Electro Scientific Industries, Inc. warrants each instrument and component parts to be free from defects in material and workmanship. Electro Scientific Industries, Inc. will service any instrument and replace parts thereof (except tubes, fuses and batteries) which shall, within one year after making delivery to the original purchaser, prove to be unsatisfactory.

If the fault has been caused by misuse or abnormal conditions or operation, a nominal charge will be made for repairs. In this case, an estimate will be submitted before making such repairs.

Electro Scientific Industries, Inc. reserves the right to make changes in design at any time without incurring obligation to modify units previously purchased.

Electro Scientific Industries

7524 S. W. Macadam Avenue • Portland 19, Oregon

ESI instruments are carefully engineered and made to the most exacting standards of workmanship and accuracy in a modern and well-equipped factory.

Field Engineers are maintained in principal cities as a service to our customers. Customers are invited to contact our nearest field engineer or to consult our engineering staff for further information regarding ESI instruments and their applications.

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Electro Scientific Industries
7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

BRIDGES
AND
ACCESSORIES

FEBRUARY 1963

MODEL
840

Instruction Manual

GENERATOR
DETECTOR
DC

SERIAL NUMBER_____

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INSTRUCTION MANUAL

for

MODEL 840 DC GENERATOR AND DETECTOR

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1. SPECIFICATIONS

2. CONTROLS

   2.1 GENERATOR
   2.2 DETECTOR

3. USING THE 840 DC GENERATOR-DETECTOR

4. PARTS LIST AND CIRCUIT DIAGRAM

1. SPECIFICATIONS

GENERATOR Voltage: 10 volts with internal resistance of 60 ohms and 300 volts with internal resistance of 22K ohms. Polarity reversible.

Isolation: Leakage resistance to ground greater than 10 teraohms.

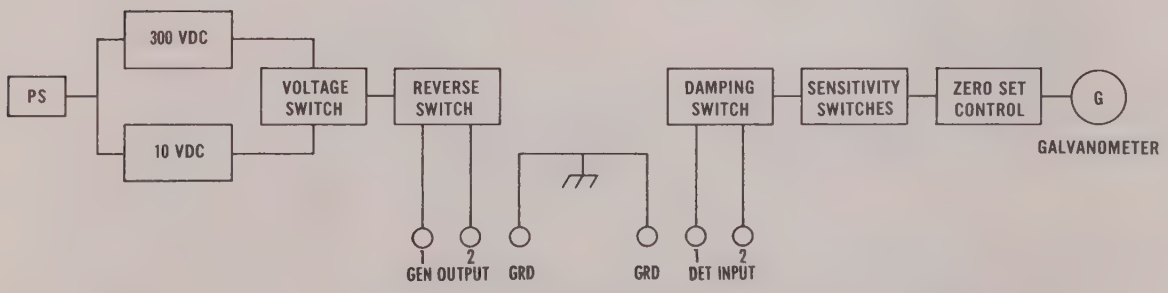
DETECTOR Galvanometer: Light beam type with vibration damping. Coil resistance approximately 300 ohms; critical damping approximately 2000 ohms.

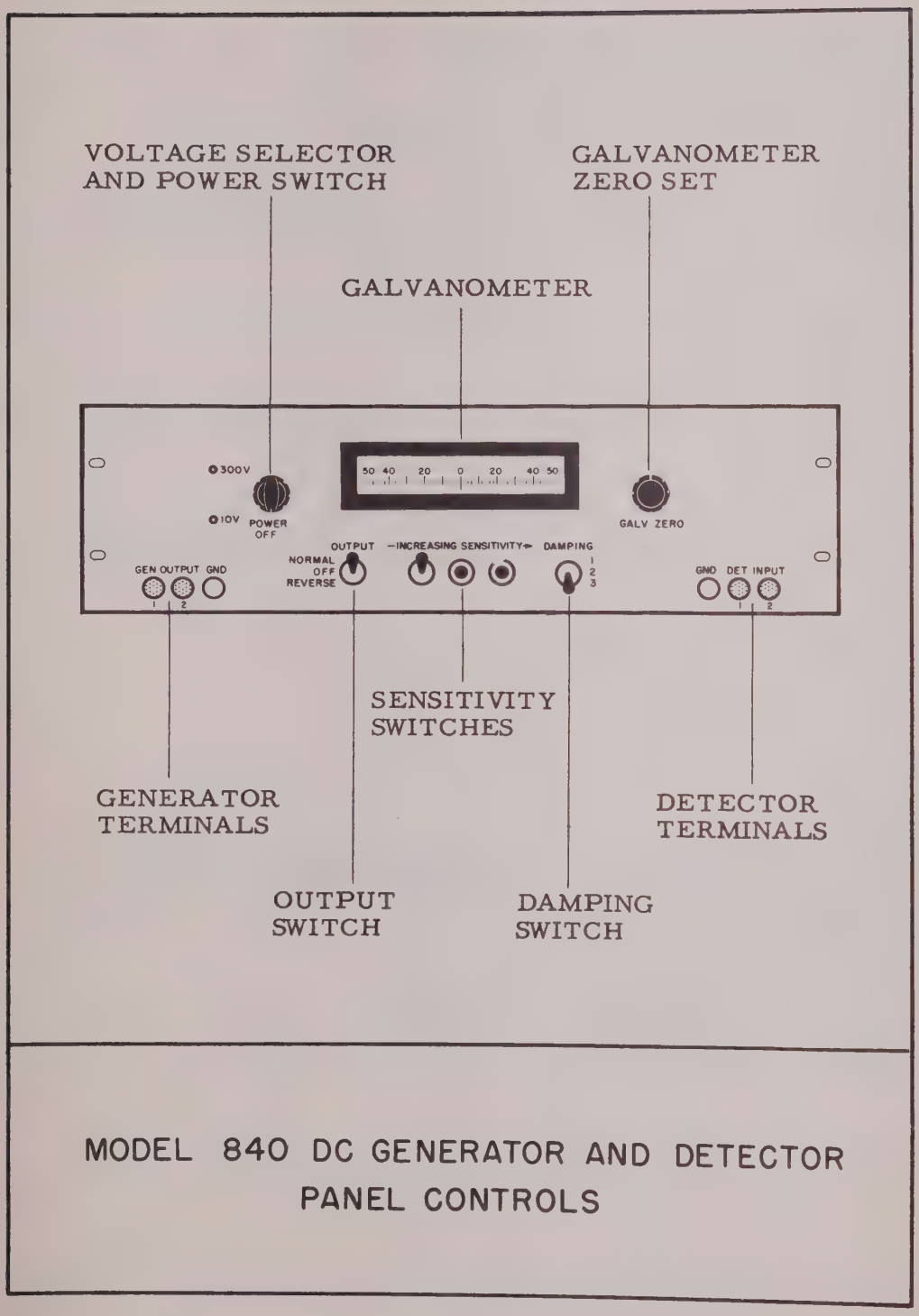
Sensitivity: A three-position switch selects 0.03, 0.60 or 12 microamperes per millimeter division.

Damping: A three-position switch selects the damping when using maximum galvanometer sensitivity.

PROTECTION: Circuit is designed so dc power output, at either 10 volts or 300 volts, cannot exceed 1 watt, which cannot damage either the bridge or the galvanometer.

POWER SUPPLY: 115 volts 50/60 cycles.





MODEL 840 DC GENERATOR AND DETECTOR
PANEL CONTROLS

2. CONTROLS

2.1 GENERATOR

Voltage Selector: The left hand control knob is used to select the generator voltage and operate the power switch. The voltage in use is indicated by the pilot light at the appropriate switch position.

OUTPUT Switch: The left hand lever switch connects the generator to the output terminals. The polarity is reversed by changing the switch position.

GEN OUTPUT Terminals: The left hand terminals are used for connecting the generator to an external circuit. Both generator terminals are well insulated from the panel. A ground terminal is provided for convenience.

2.2 DETECTOR

Galvanometer: The large window is the display for the light beam galvanometer.

GALV ZERO: The right hand control knob adjusts the zero setting of the galvanometer.

SENSITIVITY Switches: The three lever switches below the galvanometer window set the galvanometer sensitivity. Each switch has an upper "lock-in" position, a center "off" position, and a lower "momentary-contact" position. Sensitivity increases from left to right.

Damping Switch: The right hand switch selects from three damping circuits to provide optimum damping with any external resistance.

Position 1 provides series damping for use with low resistance circuits.

Position 2 provides a direct connection to the galvanometer for use with external circuits of approximately 2,000 ohms.

Position 3 provides shunt damping for use with high resistance circuits.

DET INPUT Terminals: The right hand terminals are used for connecting the detector to an external circuit. Both detector terminals are well insulated from the panel. A ground terminal is provided for convenience.

3. USING THE 840 DC GENERATOR-DETECTOR

WARNING: Before touching generator terminals, or any part of circuit, always set output switch to OFF.	This will remove the voltage from the generator terminals so that connections can be made safely.
Set all lever switches to center OFF position.	This disconnects the generator and detector from the terminals on the panel.
Connect GEN OUTPUT and DET INPUT to bridge.	Note warning above.
Check galvanometer zero.	Adjust if necessary.
Set generator voltage to 10V.	This turns on the galvanometer light beam and energizes the 10 volt power supply.
Set DAMPING switch to position 3.	This assures proper functioning of the sensitivity switches.
Set OUTPUT switch to NORMAL.	This connects the generator terminals in the normal polarity.
Turn on lowest SENSITIVITY switch.	Switch may be pressed down for momentary contact, or up for lock-in contact.
Balance bridge, turning on higher SENSITIVITY switches as null is approached.	Lower sensitivity switches can be left on if desired.
If galvanometer response is sluggish when highest SENSITIVITY switch is on, change DAMPING switch to position 1.	When highest sensitivity switch is on, position 2 of damping switch will give maximum sensitivity. If response is still sluggish, position 1 will improve response time, but may decrease sensitivity.

If sensitivity is low, try increasing output voltage to 300V.

This supplies more power to high resistance circuits.

WARNING: This 300 volts may appear on any terminal of the generator or bridge. Use caution!

Before making any circuit changes, return switches to:

OUTPUT-------OFF
SENSITIVITY---OFF

These settings will protect the bridge and the operator.

4. PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spares to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering parts from the factory include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

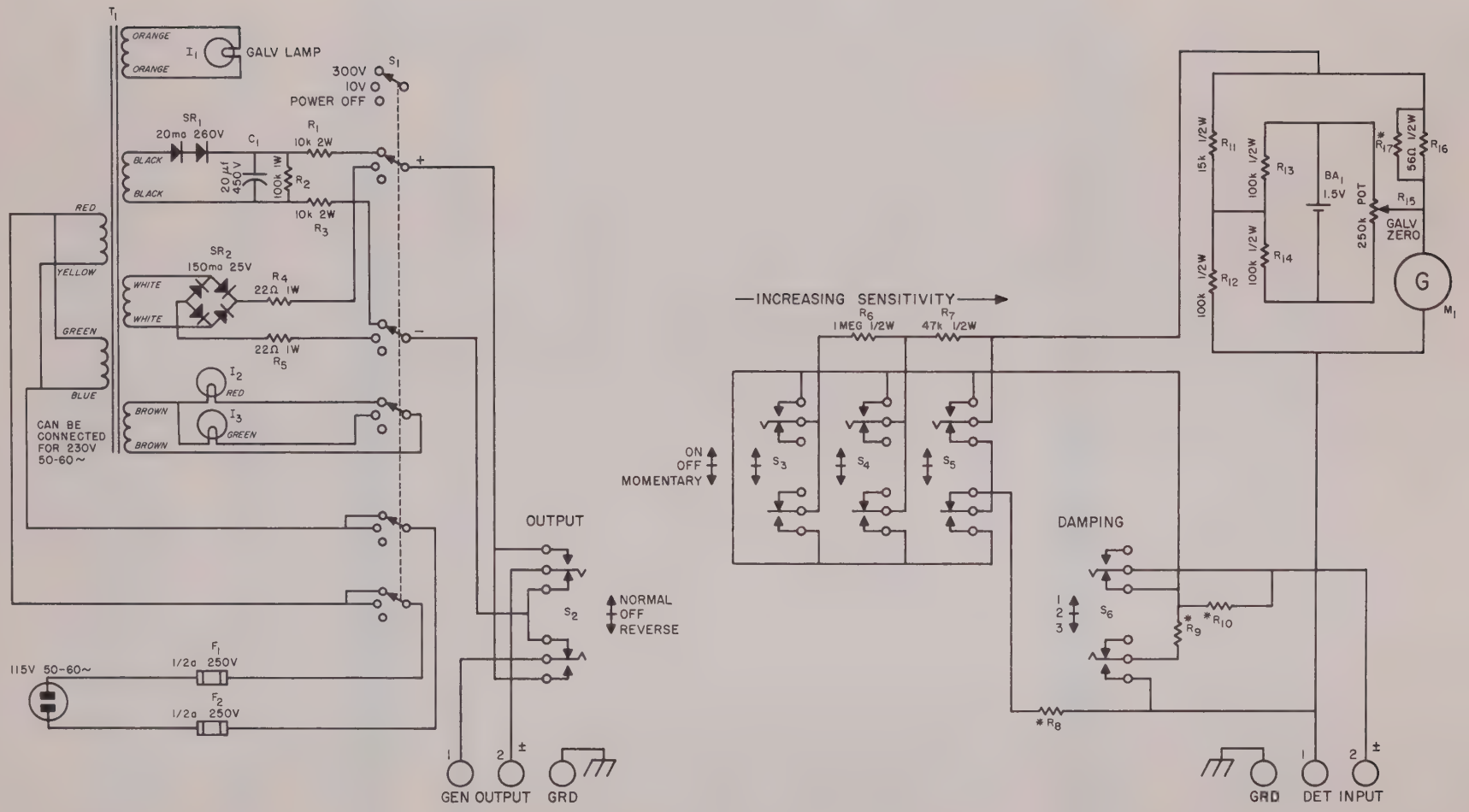
01121	ALLEN-BRADLEY CO. Milwaukee, Wis.
11711	GENERAL INSTRUMENT CORP., Semiconductor Division Newark, N. J.
11837	ELECTRO SCIENTIFIC INDUSTRIES Portland, Ore.
13567	INTERNATIONAL TELEPHONE AND TELEGRAPH CORP Roanoke, Va.
24455	GENERAL ELECTRIC, Lamp Division Cleveland, Ohio
37942	P R MALLORY AND CO. Indianapolis, Ind.
75915	LITTLEFUSE, INC. Des Plains, Ill.
82389	SWITCHCRAFT, INC. Chicago, Ill.

83740 EVEREADY, Division of National Carbon
Division of Union Carbide Corp.
New York, N. Y.

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
BA_1	Battery, Flashlite, D cell	83740		1	1
C_1	Cap, Elect, 20μf, 400 wvdc, Mfr PN TC 75	37942	1428	1	
$F_{1,2}$	Fuse, 1/2 amp, 250v, Mfr PN 3AG	75915	1802	2	2
I_1	Lamp, Galv, Mfr PN 1073	24455	5271	1	2
$I_{2,3}$	Lamp, Pilot, Mfr PN 47	24455	1800	2	2
M_1	Galvonometer	11837	3027	1	
R_1	Res, Fxd, Comp, 10K ±10%, 2w, Mfr PN HB 1031	01121	2016	2	
R_2	Res, Fxd, Comp, 100K ±10%, 1w, Mfr PN GB 1041	01121	2022	1	
R_3	Same as R_1				
$R_{4,5}$	Res, Fxd, Comp, 22Ω ±10%, 1w, Mfr PN GB 2201	01121	1981	2	
R_6	Res, Fxd, Comp, 1 meg ±10%, 1/2w, Mfr PN EB 1051	01121	1959	1	
R_7	Res, Fxd, Comp, 47K ±10%, 1/2w, Mfr PN EB 4731	01121	1958	1	
R_8	Res, Fxd, Comp, Factory Selected Value	01121		1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_9	Res, Fxd, Comp, Factory Selected Value	01121		1	
R_{10}	Res, Fxd, Comp, Factory Selected Value	01121		1	
R_{11}	Res, Fxd, Comp, 15K ±10%, 1/2w, Mfr PN EB 1531	01121	2017	1	
$R_{12, 13, 14}$	Res, Fxd, Comp, 100K ±10%, 1/2w, Mfr PN EB 1041	01121	1963	3	
R_{15}	Res, Var, 250K, 2w, Mfr PN JV 250K	01121	3075	1	
R_{16}	Res, Fxd, Comp, 56Ω ±10%, 1/2w, Mfr PN EB 5601	01121	1997	1	
R_{17}	Res, Fxd, Comp, Factory Selected Value	01121		1	
SR_1	Rect, Selenium, 20ma, 260v, Mfr PN 20Y7746	11711	2535	1	
SR_2	Rect, Selenium, 150ma, 25v, Mfr PN 1015	13567	3981	1	
S_1	Sw, Rot., Power	11837	3054	1	
S_2	Sw, Lever, Output, Mfr PN 13036L	82389	3071	2	
$S_{3, 4, 5}$	Sw, Lever, Sensitivity, Mfr PN 13036T	82389	3072	3	
S_6	Sw, Lever, Damping, Same as S_2				
T_1	Trans, Power	11837	3012	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
	MISCELLANEOUS				
	Knob	11837	1268	1	
	Knob	11837	1270	1	
	Cap, Binding Post, Metal	11837	1172	2	1
	Cap, Binding Post, Ins	11837	1170	4	2
	Binding Post	11837	1393	6	
	Scale, Galvo	11837	3087	1	
	Mirror and Support	11837	3035	1	
	Ins, Binding Post, Rear	11837	8823		
	Contacts, Battery	11837	3085	1	
	Clip, Battery	11837	3081	1	



* FACTORY SELECTED VALUES

MODEL 840 DC GENERATOR-DETECTOR CIRCUIT DIAGRAM

CLAIM FOR DAMAGE IN SHIPMENT

This instrument should be tested upon receipt. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be forwarded to us by the claim agent. We will then advise you of the disposition to be made and arrange for repair or replacement. Include model and serial number when referring to this instrument.

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Electro Scientific Industries

7524 S. W. Macadam Avenue • Portland 19, Oregon

ESI instruments are carefully engineered and made to the most exacting standards of workmanship and accuracy in a modern and well-equipped factory.

Field Engineers are maintained in principal cities as a service to our customers. Customers are invited to contact our nearest field engineer or to consult our engineering staff for further information regarding ESI instruments and their applications.

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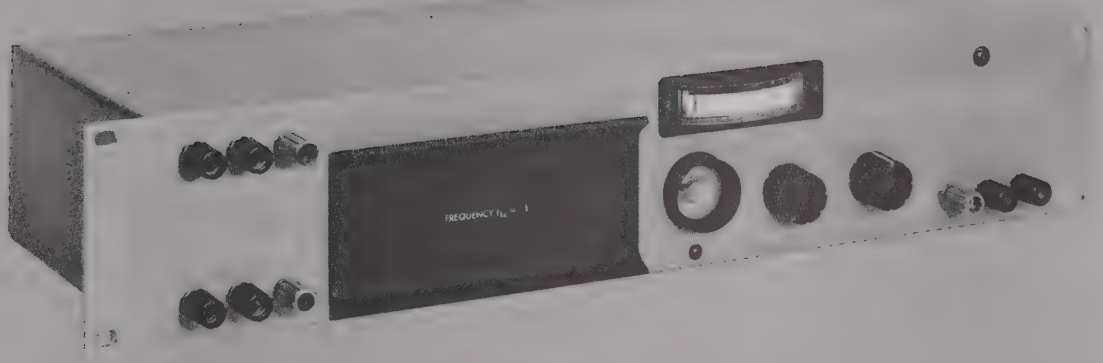
Instruction Manual

Electro Scientific Industries

7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

BRIDGES AND ACCESSORIES

JULY 1962



Model 860 A

AC GENERATOR-DETECTOR

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INSTRUCTION MANUAL
for
MODEL 860A AC GENERATOR AND DETECTOR

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        - 1.2.2 Visual Null Indicators
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        - 1.2.4 Detector Output Terminals
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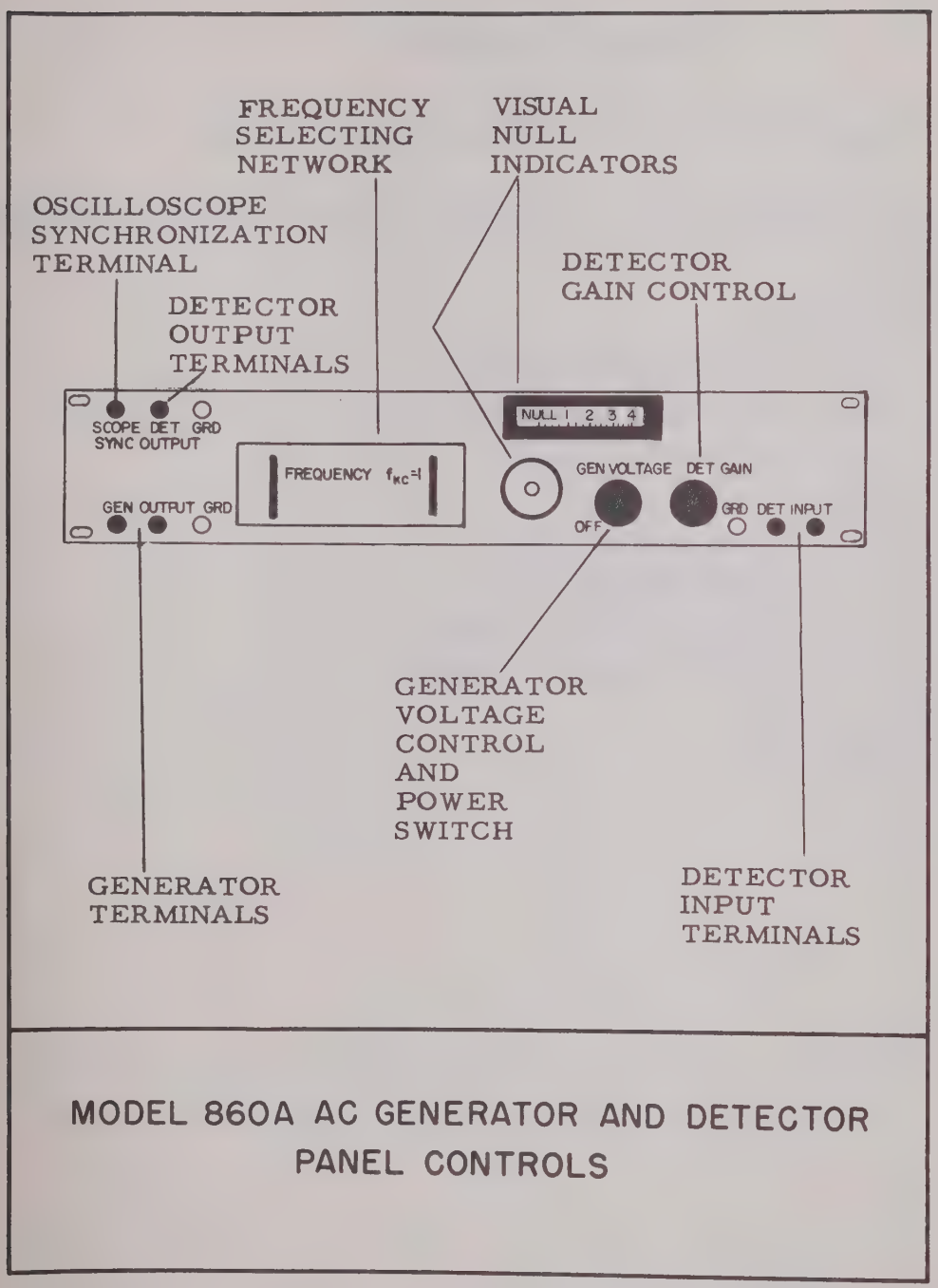


MODEL 860A AC GENERATOR AND DETECTOR PANEL CONTROLS

1. CONTROLS

1.1 GENERATOR

1.1.1 Generator Voltage Control: The left hand knob controls the output voltage of the generator and operates the external power switch.

1.1.2 Frequency Selecting Network: The plug-in unit determines the operating frequency of both the generator and detector.

1.1.3 Generator Terminals: The lower left hand terminals are for connecting the generator to the bridge circuit. Both generator terminals are insulated from, and have low capacitance to, ground. A ground terminal is provided for shield connections.

1.2 DETECTOR

1.2.1 Detector Gain Control: The right hand knob varies the sensitivity of the lower half of the eye tube and the meter null indicator.

1.2.2 Visual Null Indicator: The dual electron ray null indicator provides an extremely broad range of sensitivity. The upper eye responds to large signals and lower eye and meter responds to very weak signals. A null is indicated by the maximum opening of both eyes and null reading on the meter.

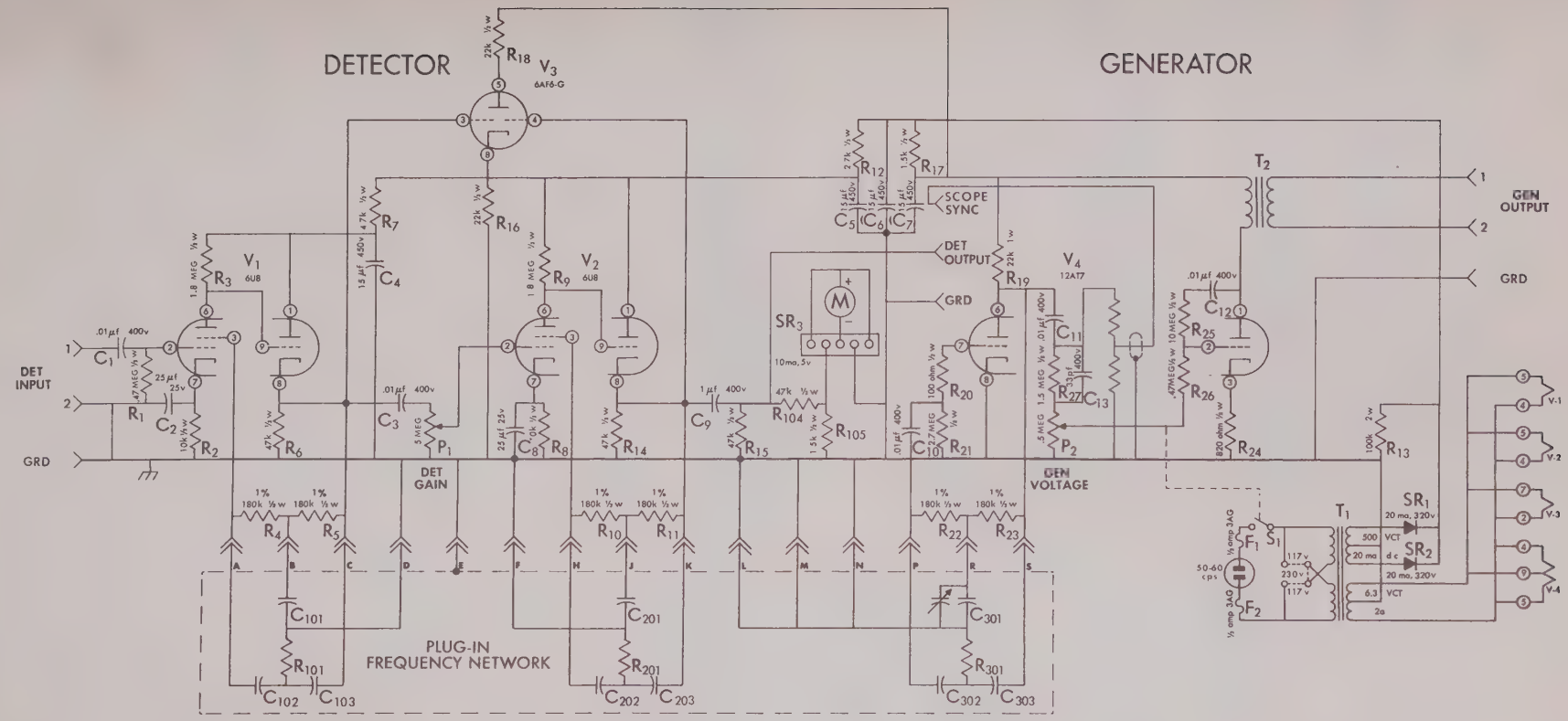
1.2.3 Detector Input Terminals: The lower right hand terminals are used for connecting the bridge circuit to the detector. The left hand terminal of this pair is internally grounded at the first stage of the amplifier. To minimize ground loop errors, the bridge circuit should be grounded only through this terminal. The terminal marked GRD is connected directly to the panel, and is provided for shield connections.

1.2.4 Detector Output Terminals: The upper left hand terminals are for connecting an oscilloscope or other indicator to the output of the detector amplifier. They are in parallel with the lower eye and meter null indicators.

1.2.5 Oscilloscope Synchronization Terminal: Between the upper left hand terminal and GRD a synchronizing signal for an oscilloscope is available. The null signal can be presented as a Lissajous elipse or a synchronized sine wave on an external oscilloscope.

2. USING THE 860A AC GENERATOR AND DETECTOR

CONNECT GENERATOR OUTPUT AND DETECTOR INPUT TO BRIDGE	Set generator voltage control to off for safety.
SET GENERATOR VOLTAGE CONTROL SO THAT THE REFERENCE MARK IS POINTED UP	This turns on the power supply, and provides sufficient generator voltage for most measurements.
SET DETECTOR GAIN CONTROL SO THAT THE REFERENCE MARK IS POINTED UP	This provides sufficient detector sensitivity for most measurements.
BALANCE BRIDGE	The null is indicated by maximum opening of both eyes and a NULL reading on the meter. The pattern edges of the eye will be sharp at null but will remain fuzzy for a minimum which is not a true null.
IF ADDITIONAL SENSITIVITY IS NEEDED, INCREASE THE GENERATOR VOLTAGE AND/OR DETECTOR GAIN	Maximum sensitivity may be needed for bridge measurements of very high or very low impedances.



Model 860A AC GENERATOR-DETECTOR CIRCUIT DIAGRAM

PARTS LIST

ESI MODEL 860A

REFERENCE DESIGNATION	PART NO.	DESCRIPTION
		CAPACITORS
C_{13}		Capacitor, 33pf, 5%, 400v, Arco
C_1, C_3, C_{10}, C_{11}, C_{12}, C_{14}		Capacitor, 0.01μf, ± 20%, 400v, Sprague
C_9	1430	Capacitor, 0.1μf, 200v, Vitamin Q 19P1049252 Sprague
C_2, C_8		Capacitor, 25μf, 25v, Sprague
C_4, C_5, C_6, C_7	5273	Capacitor, 15-15-15-15μf, 450v, Sprague 448778
C_{101}, C_{201}		*Capacitor, 2500pf, 1%, 500v
C_{102}, C_{103}, C_{202}, C_{203}, C_{302}, C_{303}		*Capacitor, 1000pf, 1%, 500v (OSC) Arco
C_{300}		*Capacitor, Trimmer, Arco 467
		CONNECTORS
P_1	2527	*Plug, Cannon, DP-2-15-33-1
J_1	2531	Receptacle, Cannon, DP-2-15-34-B
		DIODES
SR_1, SR_2	2535	Rectifier, Solenium Selectron 20Y2B
SR_3	1805	Bridge, Rectifier Conant Type B

REFERENCE DESIGNATION	PART NO.	DESCRIPTION
		RESISTORS
R_{20}		Resistor, 100 ohms, 10%, 1/2w AB
R_{24}		Resistor, 820 ohms, 10%, 1/2w AB
R_{17}		Resistor, 150 ohms, 10%, 1/2w AB
R_{12}		Resistor, 2700 ohms, 10%, 1/2w AB
R_{7}		Resistor, 4700 ohms, 10%, 1/2w AB
R_{2}, R_{8}		Resistor, 10,000 ohms, 10%, 1/2w AB
R_{16}, R_{18}		Resistor, 22,000 ohms, 10%, 1/2w AB
R_{19}		Resistor, 22,000 ohms, 10%, 1w AB
R_{6}, R_{14}, R_{15}		Resistor, 47,000 ohms, 10%, 1/2w AB
R_{13}		Resistor, 100k, 1%, 2w AB
R_{4}, R_{5}, R_{10} R_{11}, R_{22}, R_{23}		Resistor, 180k, 1%, 1/2w Electron
R_{1}, R_{26}		Resistor, 470k, 10%, 1/2w AB
R_{27}		Resistor, 1.5 MEG, 10%, 1/2w AB
R_{3}, R_{9}		Resistor, 1.8 MEG, 10%, 1/2w AB
R_{21}		Resistor, 2.7 MEG, 10%, 1/2w AB
R_{25}		Resistor, 10 MEG, 10%, 1/2w AB
R_{101}, R_{102}		* Resistor, 58k, 1%, 1/2w DC Electra (AMF)
R_{103}		* Resistor, 51k, 1%, 1/2w DC (OSC)
R_{104}		Resistor 47k, 10%, 1/2w AB
R_{105}		Resistor 1500 ohms, 10%, 1/2w AB

REFERENCE DESIGNATION	PART NO.	DESCRIPTION
		TRANSFORMERS
T_1	2514 B	Transformer, Power, Triad 8BQ4
T_2	7793	Transformer, Interstage, Merit A-2917
		ELECTRON TUBES
V_1, V_2	5275	Tube, 6U8, Miniature
V_3	5274	Tube, 6AF6G, Octal
V_4	5276	Tube, 12AT7, Miniature
		METER MOVEMENT
M_1	3140	Simpson, Model 1522C, Special scale

* Contained in the 1kc Plug-in Frequency Network only.

RECOMMENDED SPARE PARTS LIST
ESI MODEL 860A AC GENERATOR DETECTOR

ITEM	PART NO.	DESCRIPTION	RS*
1.	1268	Knob	1
2.	1294	Cap, Binding Post Ins.	2
3.	1296	Cap, Binding Post Metal	1
4.	1393	Binding Post	2
5.	2755	Tube Shield, Eye	1
6.	1805	Rectifier Type B	1
7.	3140	Meter	1
8.	2675	Transformer	1
9.	3400	Network Assy 1 kc	1
10.	1277	Washer, Shoulder	2
11.	2525	Adapter	1
12.	3175	PC assy, Amplifier Osc	1
13.	3123	Dust Cover	1
14.	5274	Tube 6AF6G	2
15.	5275	Tube 6U8	3
16.	5276	Tube 12AT7	2
17.	1802	Fuse 1/2 amp	4

*Recommended for sparing to sustain operation for 18 months.

esi PORTLAND, OREGON

INSPECTION DIRECTIONS

FINAL INSPECTION DI

Model 290-A
Final Assembly No._____
Outline Drawing No._____

EQUIPMENT USED FOR 290-A INSPECTION:

1. Resistance Measuring System ESI Model 242

2. Standard Capacitors as follows:
   E-272, 1000 pf, Leeds & Northrup type 024
   E-175, 10000 pf, Leeds & Northrup type 024
   E-173, 0.1 uf, Leeds & Northrup type 024
   E-187, 1 uf, Southern Electronics type PO-1
   E-188, 10 uf, Southern Electronics type PO-10

3. Standard Inductors as follows:
   E-118, 1 mh, General Radio type 1482-E
   E-119, 10 mh, General Radio type 1482-H
   E-120, 100 mh, General Radio type 1482-L
   E-121, 1 h, General Radio type 1482-P
   E-122, 10 h, General Radio type 1482-T

4. E-125, "D" Box

5. D.C. Detector-Generator ESI Model 840

6. A.C. Detector-Generator, ESI Model 860

AH R. Elliott
DATE 19 Jul, 1962
APPD NEM
DATE 7/20/62
PAGE 1 OF 11

DIRECTIONS	NOTES
RANGE RESISTOR TESTS 1. Set "Circuit Selector" to "R" Connect UNKNOWN terminals of 242 Bridge as follows:	
242 Bridge Terminal No. — 290-A Bridge Terminal	
1 — High end of 10k ohm standard resistor	This is the end toward panel.
2 — DC GEN 2	Make sure active jaw of Kelvin Klip goes into binding post.
3 — UNKNOWN 1	Same as above
4 — DC DET 2	
Test 1 ohm on 10^{-4} mult., 10 ohm on 10^{-3} mult., etc... Record readings on Inspection Record Sheet.	
2. Set Circuit Selector to "G"	
Connect UNKNOWN terminals of 242 Bridge as follows:	
242 Bridge Terminal No. — 290-A Bridge Terminal	
1 — DEKASTAT ADJ 2	Set main dial Dekastat to 0.0000
2 — DC GEN 1	Make sure active jaw of Kelvin Klip goes into binding post.
3 — UNKNOWN 1	Same as above.
4 — DC DET 2	
Test 1 ohm on 100 mult, 10 ohm on 10 mult etc.. Record readings of Inspection Record Sheet	

R Elliott
19 July 1962
Wem
7/20/62

DIRECTIONS	NOTES
STANDARD RESISTOR TEST	
Set Circuit Selector to "G"	
Connect UnKNOWN terminals of 242 Bridge as follows:	
242 Bridge Terminal # — 290-A Bridge Terminal	
1 — DEKASTAT ADJ 1	
2 — D-Q ADJ 2	Make sure active jaw of Kelvin Klip goes into binding post.
3 — UNKNOWN 2	Same as above
4 — DC GEN 2	
Measure 10k Standard Resistor & record deviation on Inspection Record Sheet.	
MAIN DIAL DEKASTAT	
Set Circuit Selector to "R"	
242 Bridge Terminal # — 290-A Bridge Terminal	
1 — DC DET 1	Make sure active jaw of Kelvin Klip goes into binding post.
2 — D-Q ADJ 2	
3 — UNKNOWN 2	Same as above
4 — DC GEN 1	
Check rheostat at zero and at 10 division increments.	The zero resistance of the 10.5 ohm rheostat will be approximately 75 to 100 milliohms.
Connect UNKNOWN terminals of 242 Bridge as follows:	
242 Bridge Unknown Terminal — 290-A Bridge Terminal	
1 — DEKASTAT ADJ 2	

R. Smith
19 July 1962
Nem
7/20/62

DIRECTIONS		NOTES
(MAIN DIAL DEKASTAT CONT.)		
2	Low side of 10.5 ohm rheostat	Make sure Kelvin Klip does not short out 1-ohm deck.
3	UNKNOWN 2	Make sure active jaw of Kelvin Klip goes into binding post
4	DC GEN 1	
Measure and record deviations, of 10 ohm, 100 ohm, and 1K decades.		
FUNCTIONAL CHECKS		
Series Capacitance		
Place shield can over range stack and secure		
Install 290A in a rack with the 840 and 860.		Use a 1kc network in the 860
Set Circuit selector to "C" Series		
Set D-Q mult to .001X		
Set Range Switch to 10^{-2} uf		
Connect E-173 capacitor to UNKNOWN terminal of 290-A.		Lo terminal of capacitor should connect to terminal No. 1
Set main dial Dekastat to actual value of E-173.		
Adjust standard capacitor adjustment simultaniously with D-Q dial to obtain a null on the 860.		
Record D reading and C readings on Inspection Record Sheets.		

R. Elliott
19 July 1962
NEM
7/20/62

DIRECTIONS	NOTES
Connect E-187 capacitor to UNKNOWN terminals of 290-A. Set Range switch to 10^{-1} uf Adjust D-Q dial and main dial Dekastat simultaneously to obtain a null on 860-R. Record D and C readings on Inspection Record Sheets.	
Connect E-188 capacitor to UNKNOWN terminals of 290-A. Set Range switch to 1 uf Adjust D-Q dial and main dial Dekastat simultaneously to obtain a null on the 860-R. Record C and D readings on Inspection Record Sheets.	Use short, heavy leads in order to avoid D error.
Set range switch to 10 uf Adjust D-Q dial and main Dekastat to obtain a null on the 860-R. Record C and D readings on the Inspection Record Sheets.	E-188 should still be connected to the 290-A
Set range switch to 100 uf Adjust D-Q dial and main dial Dekastat to obtain a null on the 860-R. Record C and D readings on the Inspection Record Sheets.	E-188 should still be connected to the 290-A.
Set range switch to 10^{-3} Connect E-175 to UNKNOWN terminals of 290-A.	Connect to Lo side to terminal No. 1 of the 290-A

DIRECTIONS	NOTES
Adjust D-Q dial and main dial Dekastat to obtain a null on 860-R. Record C and D readings on the Inspection Record Sheets.	
Set range switch to 10^{-4} Connect E-272 to UNKNOWN terminals of 290-A	A shielded lead should be used to connect UNKNOWN 1 of the 290-A to the low side of E-272. The connector at the 290-A end should completely shield UNKNOWN 1 from UNKNOWN 2. The connector at the capacitor end should completely shield the low terminal from the high terminal. The lead from UNKNOWN 2 to the high side of E-272 can be any short piece of wire.
Adjust D-Q dial and main dial Dekastat to obtain a null on 860-R Perform calculations as shown on Inspection Record Sheets. C and D errors should be less than 3/4 of our catalog specifications, which are as follows:	

C RANGE	C ACCURACY	D ACCURACY
Highest	0.2% ±1 dial div. ±0.5% x $Dx\frac{f}{kc}$	$0.005\frac{f}{kc}(1+D^2) + 0.02D$
Other 5	0.1% ±1dial div. +0.5% x $Dx\frac{f}{kc}$	$0.005\frac{f}{kc}(1+D^2) + 0.02D$
Lowest	0.2% +1 dial div. +1.0% x $Dx\frac{f}{kc}$	$0.010\frac{f}{kc}(1+D^2) + 0.02D$

19 July 1962

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DIRECTIONS	NOTES
SERIES L Set D-Q multiplier to 0.1X Set Circuit Selector to SERIES L Set Range Switch to 10^{-4} Set main dial Dekastat to approx. 10.0000 Connect E-118 to UNKNOWN terminals of 290-A Adjust Q and C dials to obtain a null on the 860. Record Readings on Inspection Record Sheet.	Use short leads. Connect Low side to UNKNOWN 1
Set range switch to 10^{-3} Connect E-119 to UNKNOWN terminals of the 290-A Adjust Q and C dials to obtain a null Record readings on the Inspection Record Sheet.	
Set range switch to 10^{-2} Connect E-120 to UNKNOWN terminals Adjust dials to obtain a null Record reading on the inspection Record sheet.	
Set range switch to 10^{-1} Connect E-121 to UNKNOWN terminals Adjust dials Record readings on the Inspection Record Sheet.	It is necessary to put a 77 ohm resistor in series with this inductor to spoil its Q so it can be read on the Q dial.

DIRECTIONS	NOTES
Set range switch to 1 Connect E-122 to 290-A Bridge Adjust dials Record Readings	The low side of E-122 should be connected to its case. The lead from UNKNOWN 1 of the 290 should be shielded. The shield should enclose the low and case terminals of the inductor without touching them. The high side of the inductor can be connected to UNKNOWN 2 of the 290 with any short test lead.
Set range switch to 10 Set main dial Dekastat to approx. 1.0000 Adjust dials Record Readings	E-122 should still be connected to the 290-A.
Set range switch to 100 Set main dial Dekastat to approx. 0.1000 Adjust dials Record readings	Same as above

L. Scott
19 July 1962
7/20/62
8 11

DIRECTIONS	NOTES

Convert Q readings to D readings, using the formula D equals 1/Q

Subtract the actual value of D from the calculated D.

L and D errors should be less than 3/4 of the catalog specifications, which are as follows:

L RANGE	L ACCURACY	D ACCURACY
Highest	0.2% + 1 dial div. + 1.2% x f_{kc}/Q	$0.012 f_{kc} (1+Q^2)+0.02Q$
Other 5	0.1% + 1 dial div. + 0.7% x f_{kc}/Q	$0.007 f_{kc} (1+Q^2)+0.02Q$
Lowest	0.2% + 1 dial div. + 0.7% x f_{kc}/Q	$0.007 f_{kc} (1+Q^2)+0.02Q$

PARALLEL INDUCTANCE	
Set D-Q multiplier to .01X	
Set circuit selector to L Parallel	
Set range switch to 10^{-2}	
Set main dial Dekastat to approx. 10.18	
Connect E-120 to UNKNOWN terminals of the 290-A	Connect low side to UNKNOWN 1
Balance Bridge	
Record Readings	
See that readings are within limits shown on Inspection Record Sheets.	

R. Elliott
19 Jul, 1962
Mem
7/20/62

DIRECTIONS	NOTES
PARALLEL CAPACITANCE Set D-Q multiplier to .1X Set circuit selector to C PARALLEL Set range switch to 10^{-2} Set main dial Dekastat to approx. 9.9000 Connect E-125 to UNKNOWN terminals of the 290-A Set E-125 to D equals 0.1 Balance Bridge Record readings See that readings are within limits shown on Inspection Record sheet.	
FUNCTIONAL D.C. TESTS Set circuit selector to R Set range switch to 10^{-4} Set main dial Dekastat to approx. 0.0025 Connect shorting bar to UNKNOWN terminals of the 290-A Balance Bridge, using the 840 detector Record reading on Inspection Record	
Set main dial Dekastat to 10.0025 Connect a 1 ohm resistor to UNKNOWN terminals of the 290A Balance Bridge Record readings on inspection record sheet.	

A. Short
12 July 1962
Mem
7/20/62

DIRECTIONS	NOTES
Set circuit selector to G Set range switch to 100 Balance bridge Record readings	
Set range switch to 10^{-2} Connect a 10K resistor to the UNKNOWN terminals of the 290A Balance Bridge Record readings. Set circuit selector to R Set range switch to 1 With the 10K resistor still connected to the 290A, balance bridge and record readings. See that all the R and G readings fall within the tolerances shown.	

WRITTEN R. Elliott
DATE 19 July 1962
APPROVED [signature]
DATE 7/20/62

LATCH LOCK
BINDER Made by
BEAVERITE
BEAVER FALLS, N.Y.
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